Dr. S. P. Willcocks
with authors' compliments.

Central Cocoa Research
Station, Tafo.
Rec'd 10th MAY 1944
No.

GOLD COAST COLONY

DEPARTMENT OF AGRICULTURE

Report

on the

Central Cocoa Research Station, Tafo, 1938-42

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M. GREENWOOD, M.B.E.

Price : 4s.

GOLD COAST
PRINTED BY THE GOVERNMENT PRINTING DEPARTMENT, ACCRA
1943

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PREFACE

THE first, and last report on the Central Cocoa Research Station at Tafo, appeared in 1938.* It outlined the objects of the Station and the programme projected for it : it gave an account of the pioneer work which had been accomplished between March, 1938 and its opening in June, 1937.

The Station owes its creation to the visit which Sir Frank Stockdale, then Agricultural Adviser to the Secretary of State for the Colonies, paid West Africa in 1935. It was apparent at that time that production in the Eastern Province, the cradle of the Gold Coast cocoa industry, was on the decline : areas of hitherto normal productivity were being abandoned, and the country's exports were being maintained by the construction of new farms in Ashanti and the Western Province. Without facilities for research the Department was ill-fitted to give advice on the re-establishment of cocoa in the derelict areas or, indeed, to say whether rehabilitation was possible. It was known that the establishment of cocoa was more difficult than it had been in the early days of the industry. The difficulty had been variously ascribed, often on slender evidence, to soil exhaustion, to deterioration of the eco-climate and to the greater incidence of pests and diseases. Sir Frank recommended the establishment in the Eastern Province of a research station which should determine the relative magnitude of these factors and devise means whereby the yield of existing farms might be maintained even if the resurrection of abandoned areas was not found possible.

Estate practice in the older cocoa-growing countries embodies a number of devices, wind-breaks, overhead shade, mulching, etc., aimed at nursing the tree by the regulation of its environment. These devices are foreign to native practice, and the early success of cocoa in this country had suggested that they were not necessary. Experiments to decide whether their adoption will promote the establishment of young cocoa, or improve the health and yield of older trees, form a large part of the Station programme.

The most obvious method of maintaining yield over a diminishing acreage lies in the substitution of low-yielding stock by planting material selected for its high-yielding capacity. Selection for yield and bean size was begun in 1937 by careful combing of the records of individual trees of Amelonado type which had been taken on departmental farms from 1914 onwards. Material was later collected from Amelonado and hybrid (Trinitario) types in a large number of native farms. This phase of the Station's activity was particularly welcomed at the Third West African Agricultural Conference held in Nigeria in 1938, when it was decided that selections made in other Colonies should be multiplied and tested at Tafo.

* Wright, J., Gold Coast Department of Agriculture Bulletin No. 36, 1938.

The original breeding programme included the secondary item " Selection for resistance to pests and diseases ". It was not then foreseen that within a short time the production of a strain resistant to a particular disease, Swollen-shoot virus, would become necessary for the maintenance of cocoa in the Eastern Province, possibly throughout the Colony. First recognised in 1936 within ten miles of Tafo, it was discovered on the Station in 1939. The virus nature of the disease, previously considered to be a concomitant or a consequence of exposure, had been demonstrated at Tafo in 1939. Further work on its symptomatology and the discovery of several strains of differing virulence have revealed a close similarity to Peach Mosaic, which the Botanist studied in the United States in 1941. Its rate of spread and some of the means of transmission are known : a method of treatment has been devised which eliminates the disease from small outbreaks.

Surveys of the disease have shown conclusively that outbreaks are not always associated with deforested conditions : the fact that the first and largest outbreak occurred in a deforested area may be significant in that the removal of forest trees may have induced the insect vector of a virus of indigenous trees to feed on cocoa. Probably several infections from the indigenous host have occurred : this would account for the appearance of the disease in places as remote as Wiawso and Peki. Records of its appearance following the felling of forest trees in native farms are many ; two instances have been noted on the Station itself.

It can now be stated most definitely that the swollen-shoot virus is a cause of rapid and usually lethal form of dieback of cocoa of all ages and is not in any way a consequence of other forms of dieback, such as that due to Capsid attack or drought. Surveys of swollen-shoot and Capsid dieback now show that drought is a limiting factor only on the fringe of the forest belt.

Treatment has been aimed at confining the disease to the Eastern Province. A staff trained at Tafo in the recognition of its symptoms has made an intensive survey of the natural forest and mountain barriers separating the Eastern from the Central Province and Ashanti. Diseased and contact trees have been cut out. Spraying to prevent the spread of cocoa Psyllids from infected trees was incorporated after preliminary work had shown that the virus could be transmitted by this insect. Later work has, however, shown that two species of Mealy Bug and the Cocoa Aphis are also vectors, and spraying, which slows down the rate of survey, has been temporarily discontinued.

The distribution of Capsids, insect pests of cocoa whose depredations are scarcely less serious than those of the virus, has been studied in relation to climatic conditions and the fruiting and flushing cycles of the tree. Spraying trials with a number of insecticides have been made, and seasonal variation in the degree of parasitism has been measured. Selection for strains tolerant of Capsid attack has been started.

The soil types of the Station have been described, and analysis has shown that the average surface soil compares favourably with the best Gold Coast cocoa soils and reaches the standard of adequacy prescribed for " good " West Indian soils of comparable texture. The analysis of pairs of soils from diseased and healthy trees in a number of farms affected by swollen-shoot disease has shown no difference in their nutrient status. The evaporation rate under unshaded cocoa at Tafo has been shown to have a value close to the mean of a number of determinations made throughout the cocoa belt, and to be much lower than that recorded on " good " Trinidad estates.

War had broken out before the whole of the staff had taken up residence in Tafo, and it will be seen from the staff list that the work of many has devolved on a few. The first two Superintendents, Messrs. Wright and Skidmore, and the Pathologist, Mr. Shepherd, have been on active service during the greater part of the period covered by this report. Mr. Squibbs was able to take charge of the Station after his release from military service in 1940. The pathological work has been carried out by the Botanist, Mr. Posnette, who has also acted for the Entomologist during his absence on leave. The Entomologist has been responsible for the treatment measures taken during the survey of native farms for swollen-shoot disease, besides acting as Superintendent at a time when he was alone on the Station. The Chemist has been chiefly engaged with crops of higher war potential than cocoa, which has temporarily been relegated to the rank of an unexportable oil-seed. During 1942 the Superintendent has been called on to rear livestock and to produce vegetables for military consumption : the Department has been justly proud of the results he has achieved.

Annual reports, intended for publication, have been made by all members of the staff. Their publication has not been possible under present circumstances. A summary of the work carried out to March, 1941, was prepared but has also not been published. The present report summarizes the work achieved between March, 1938 and December, 1942. The conclusions, and in most cases the words, are those of the authors of the 1941 summaries, whose names appear above their respective contributions. Indications are given where any piece of work has been presented for or received outside publication.

CENTRAL COCOA RESEARCH STATION, TAFO
REPORT FOR 1938-42

STAFF

SUPERINTENDENT-IN-CHARGE.

J. Wright, B.SC., A.I.C.T.A., March–October, 1938: April–August, 1939.

C. L. Skidmore, B.SC., DIP. AGRIC., A.I.C.T.A., October, 1938–April, 1939: November, 1939–February, 1940.

F. L. Squibbs, February–December, 1940: April, 1941 onwards.

J. Gordon, B.SC., B. AGRIC., A.I.C.T.A., December, 1940–April, 1941.

Acting.

G. S. Cotterell, August–November, 1939.

BOTANY.

Specialist: A. F. Posnette, B.A., A.I.C.T.A., April, 1938–May, 1939: December, 1939–September, 1941: March, 1942 onwards.

Acting.

E. A. Pound, B.SC., May–August, 1939

F. L. Squibbs, September, 1941–March, 1942.

CHEMISTRY.

Senior Specialist: M. Greenwood, M.SC., October, 1939–May, 1941: November, 1941 onwards.

Acting.

F. L. Squibbs, May, 1941–November, 1941.

ENTOMOLOGY.

Senior Specialist: G. S. Cotterell, A.R.C.S., D.I.C., March, 1939–April, 1940: October, 1940–October, 1942.

Acting.

A. F. Posnette, April–September, 1940: November, 1942 onwards.

PATHOLOGY.

Specialist: E. F. S. Shepherd, B.S.A., March, 1939–July, 1940.

Acting.

A. F. Posnette, July, 1940 onwards.

ADVISORY COMMITTEE

The policy of the Station is directed and research co-ordinated by an Advisory Committee, which meets periodically under the chairmanship of the Director of Agriculture. Its members include the Chief Agricultural Officer, Eastern Province, the Officer-in-charge, Division of Statistics and Surveys, and the staff resident at Tafo. Eight meetings have been held during the period reviewed.

The interest shown in the Station by the Nigerian Department of Agriculture has been greatly appreciated. Helpful advice has been received as a result of visits paid by the Director (J. R. Mackie, Esq., C.M.G.) and Messrs. O. J. Voelcker and J. West.

STATION LAYOUT

A plan of the Station is attached. Its total area is 270 acres. It is divided by an old road, passing through the Residential Area, into a northern half of 156 acres and a southern half of 114 acres.

Early development was confined to the northern half, on which cocoa had been more extensively planted. The whole of this half and 8 acres of the southern half required for building purposes had been acquired in 1938 after compensation had been paid for permanent crops established by squatters.

Eighteen acres of cocoa land in the southern half were acquired early in 1941. The remainder of the area, with the exception of 16 acres lying south of the Beyera stream, was taken over at the beginning of 1942. The second area contained only 19 acres of cocoa, and a large part has been used as a vegetable garden, for sheep-folding and for growing stock-feed and crops other than cocoa.

An estimate of the total acreage acquired at the end of 1942 is :—

(*a*)	Containing experimental cocoa or cleared for planting ... ... =	140 acres
(*b*)	Available for future planting ... ... =	26 ,,
(*c*)	Nurseries, roads, crops other than cocoa, etc. =	69 ,,
(*d*)	Buildings and grounds ... ... =	19 ,,

The area has been demarcated by concrete pillars into square 1-acre blocks, which in the experimental area are sub-divided into ¼-acre plots by plant boundaries.

A two-storey building containing Botany, Chemistry, Entomology and Pathology laboratories ; a single-storey block for the Superintendent and field staff ; five bungalows ; quarters for African staff ; a Rest House for visitors and a Power House were completed in March, 1939.

An insectary and a fermentary with attached store, workshop and drying floor were constructed in 1940. The insectary was enlarged and a greenhouse erected in 1942.

AGRONOMY

(F. L. Squibbs)

UNIFORMITY TRIAL ON ESTABLISHED COCOA

The native-established cocoa standing when the Station was acquired consisted of a number of farms containing trees of widely differing age and spacing, distributed haphazardly with respect to soil type and overhead shade. It was considered advisable to carry out a uniformity trial as a prelude to experimentation.

For two years (1938 and 1939) individual tree records were collected from an area of 69 acres (269 quarter-acre and 31 sixteenth-acre plots) in which every tree had been numbered, its girth measured (3 feet from the ground)* and its position plotted on a plan which also recorded the distribution of every shade tree and the size of its canopy. During this period the cocoa was disturbed as little as possible. A monthly count of dead and dying trees was made, and the cause of death assigned where possible : a census of the total tree population was taken annually.

Yield records for individual trees were collected from 49 acres in 1940, but in subsequent years they have been taken only on a selected number of randomised plots and plots under experiment (15 acres), plot yields being determined over the remainder of the area. The trial area was reduced to 64 acres in 1941 and to 62 acres in 1942.

From 1940 onwards the plots have been treated by methods similar to those of the native farmer, although in a manner more thorough and systematic than native practice. Treatment has included the brushing of weed growth ; the removal of mistletoe, dead branches, white thread, horse-hair blight and suckers ; the prompt removal of dead trees and replacement by quick-growing plants such as plantains and *Gmelina arborea ;* drainage of the more swampy areas ; regular harvesting. It has also been necessary to spray periodically to control *Sahlbergella* whose irregular distribution threatened to vitiate some of the experiments. Lateral protection has been afforded by planting *Cassia siamea* and *Michelia champaca* along the boundaries.

Yield

For each picking the following records have been kept : (i) total number of *pods picked* (ii) number of *pods discarded* (iii) weight of *wet cocoa* fermented (iv) weight of *dry cocoa*. From these figures, tables showing the distribution of the crop over the growing season, yield per acre and number of pods per lb. of dry cocoa at each picking have been prepared. From individual plot-yields tables and graphs showing their distribution in terms of dry cocoa and the number showing an increase or decrease compared with the preceding year have been constructed.

* Redetermined in 1940 at 1 foot above ground.

The number of pickings of the minor crop (June-August) has varied from 1 (1939, light crop) to 3 (1940 and 1942); of the main crop (September-January) from 2 (1938, labour shortage) to 6 (1941).

The yields from the 239 $\frac{1}{4}$-acre and 31 $1\frac{1}{16}$-acre plots which were still under experiment in 1942 (total 30,356 trees) are given below:—

Year	No. pods harvested	No. pods discarded	Cocoa fermented wet weight lb.	Cocoa dry weight lb.	Dry cocoa—lb. per acre		
					Minor	Major	Total
1938	697,634	109,977	114,628	50,238	157	657	814
1939	614,010	66,782	118,990	48,694	24	765	789
1940	625,681	52,206	124,025	51,453	114	720	834
1941	699,386	91,919	126,794	51,071	80	748	828
1942	583,522	60,597	108,363	46,708	48	709	757

Minor Crop: Rainfall.—It is interesting to note that the low yields in 1939 and 1942 are largely accounted for by the failure of the minor crop. The size of the minor crop appears to be negatively correlated with the amount of rain falling in the early part of the year. Only a very small part of the reduction in yield may be attributed to the higher percentage of discards recorded in the wetter periods.

Year	1939	1942	1941	1940	1938
Rainfall ins.					
(Feb. to July incl.)	48	40	33	31	29
Minor crop					
lb. dry cocoa per acre	24	48	80	114	157
Discarded pods percentage of total	32·2	32·2	26·2	15·8	5·8

Distribution of Plot Yields.—The yields of dry cocoa per $\frac{1}{4}$-acre plot have been arranged in class intervals of 50 lb. From these the yields per acre have been calculated for intervals of 200 lb.

Yield-class lb. per acre	Percentage of total number of plots in each class				
	1938	1939	1940	1941	1942
0–200	4·1	4·5	3·3	3·6	3·3
201–400	8·1	11·2	8·9	9·3	10·0
401–600	13·4	14·9	14·9	17·7	20·1
601–800	23·8	21·6	21·9	17·3	25·5
801–1000	23·4	21·9	20·1	18·6	20·9
1001–1200	13·8	14·1	17·5	17·3	12·1
1201–1400	9·3	7·1	7·8	10·9	5·0
1401–1600	1·8	4·1	3·0	4·4	2·5
1601–1800	1·5	0·7	2·2	0·8	0·4
1801–2000	—	—	0·4	—	—
Lowest plot yield per acre	55	68	74	58	60
Highest plot yield per acre	1,721	1,686	1,842	1,611	1,751

It will be seen that the distribution is fairly symmetrical, with the mean usually in the modal class. The unusual distribution in 1941, when the number of plots in the 601–800 lb. class was relatively low, will be noticed.

Analysis of Individual Tree Yields.—A preliminary analysis of the data collected during the first two years of the trial, when individual tree yields were taken over the whole area, has been made* From the spot-plans and yield data it has been possible to determine the inter-relations between the following factors :—

(i) number of pods per plot, (ii) number of stems per plot, (iii) number of pods per stem, (iv) girth per stem, (v) total per girth plot.

The effect of shade was determined between plots for the above factors and for (vi) percentage number of pods discarded (vii) death-rate of trees, all causes. The shade effect within plots was determined by comparing samples of 10 trees from the shaded and from the unshaded portions of 50 plots.

The following conclusions are of agricultural interest :—

(i) Vertical shade has a depressant effect on the average girth per tree and on the number of pods produced per tree and per plot. It has a preservative effect on general health (deaths under shade 2½ per cent without shade 4 per cent of original number during two years.)

(ii) There is reason to believe that there is no " best " planting distance for cocoa even in one locality or on one soil type. Random close planting and allowing the trees to thin themselves as they mature is probably the best practice : this is the local method.

Mortality

(*a*) *Causes other than Swollen-shoot.*—The number of trees dying per annum has been fairly constant, over the five-year period, at about 1 per cent of the tree population, which at the end of 1942 was 30,356. Roughly 40 per cent of the deaths have been attributed to *Sahlbergella* and a like number to Root Disease. Accurate diagnosis of the primary cause of death has rarely been possible.

(*b*) *Swollen-shoot Disease.*—The first outbreak was found in February, 1939. This and subsequent outbreaks were kept under observation until March, 1940, when trees showing swellings were cut out. From July to December, 1940, all trees showing symptoms of chlorosis were cut out whilst in 1941 and 1942 both infected and contact trees were removed with treatments described under Pathology (p. 61 and 62).

Native farms contiguous to the north-east boundary of the Trial Area were surveyed to a depth of 100 yds. and treated in November, 1940, when 885 infected and 930 contact trees were

* Gordon, J. " Uniformity Trial on 269 quarter-acre plots of Cocoa ". Presented to *Tropical Agriculture*, February, 1943.

removed. A second survey to a depth of 200 yds. made in August, 1941, led to the cutting out of 1,291 infected and 1,937 contact trees.

At the end of 1942 a total of 63 outbreaks, involving the removal of 736 infected and 1,134 contact trees, had been recorded in the Trial Area itself.

Growth-Rate

Girth measurements at one foot above ground were redetermined in 1940 on the single-stemmed bearing trees in 30 $\frac{1}{4}$-acre plots chosen at random. The total number of trees measured was 3,091.

The measurements were repeated after an interval of two years. The mean annual increases in girth were as follows :—

Original girth (ins.)	2–15	15–19	20–31
Increase (ins.)	0·6–0·5	0·4	0·4–0·2

Labour Costs

Itemised costs of production have been recorded. The figures for 1938–40 are summarized below. A load is 60 lb. dry cocoa, the normal unit of sale.

	1938	1939	1940
Cocoa lb. per acre	793	774	828
,, loads per acre ...	13·2	12·9	13·6
Price per load	7/10	8/–	6/8
Labour man-days per load	3·7	3·7	3·7
Labour expenditure per load	4/6	4/6	4/6
Profit per load	3/4	3/6	2/2
Profit per acre	£2 4s.	£2 5s. 1d.	£1 9s. 6d.

The total gross profit over 69 acres for three years was £412 10s. The labour charges, which include the services of a headman, but not of an overseer, may be taken as an upper limit which is not likely to be exceeded when native farms are worked by hired labour. The cost of harvesting (25 per cent of total expenditure) is greatly increased in the Uniformity Trial by the need for frequent and separate pickings for each recorded tree or plot. A profit of £2 per acre should be obtainable from an average native farm entirely employing outside help. The return is, of course, greater when the work is carried out by the owner or members of his family whose casual labour would not be marketable.

ARTIFICIAL SHADE

Artificial overhead and lateral shade have been applied to established cocoa to assess their effect on the health, habit and yield. Observations of flowering, flushing and setting have been made by the Botanist, on insect population by the Entomologist and on environmental factors by the Chemist : comparative records for these factors have also been obtained from unshaded controls and from naturally shaded trees.

Overhead Shade No. 1.—Erected June, 1940, in the least shaded part of the Station (A6). A raffia (cocoa-drying) mat 30′ x 30′ was suspended about 3′ above the canopy, which had an average height of 20′. The trees were 15 years old, average girth 14″, spaced 8′ x 8′. The mat covered 22 trees ; its sides were draped down to the top of the cocoa canopy. A belt of surrounding trees was used as control.

Overhead Shade No. 2.—Erected January, 1941, close to No. 1. A mat of wider mesh giving roughly half the shade effect of the first was used. The trees were 20 years old, average girth 16″, spaced 9′ x 9′.

Lateral Shade.—Erected May, 1940, around young cocoa newly exposed along the north west boundary. One $\frac{1}{16}$-acre plot was protected on its west and north sides by an L–shaped screen (total length 104 feet, height 14 feet) made of bamboos and palm-stems and supplemented by *Gliricidia* cuttings, plantains and *Ipomoea sp.* (Morning Glory). The trees were 15 years old, average girth 14″, spaced 7′ x 7′. Yields have been recorded for 50 shaded trees and for a like number of unshaded trees in plots lying N.E. and S.W. of the screened plot.

The three sites were photographed before shade treatment was begun. The following yields of pods per tree were obtained from 18 trees in each of the overhead treatments and controls, and from 50 trees in the lateral treatment and control :—

	Pods per Tree		
	Pre-treatment	*Treated*	
	av. 1939 and 1940	1941	1942
Overhead Shade 1	5·2	4·6	3·2
Control	17·5	22·9	12·9
Overhead Shade 2	26·9*	17·2	13·0
Control	29·1*	36·3	29·0
Lateral Shade	10·1	25·9	28·5
Control	15·3	28·3	35·2

In both the Overhead treatments, shade produced an immediate decrease in yield. No conclusions can be drawn from the lateral treatment. The effect on flowering, setting and pod production is discussed on p. 30.

* Average 1938 and 1939. 1940 not recorded.

ESTABLISHMENT

First Progeny Trial

The relative merits of four systems of temporary shade are being determined during the establishment of 16 acres of seedling cocoa representing the progeny of the first 30 of the Botanist's Amelonado selections. Permanent shade trees of six different species are also being tested against no shade.

(*a*) *Temporary Shade*

TREATMENTS

(i) *Native.*—Intended to follow the native practice of nursing the seedlings for two or three years under mixed food-crops, usually plantains, corn, cassava and cocoyams. Only plantains and cassava are used in the trial.

(ii) *Plantains and (procumbent) legume.* *Centrosema pubescens* was first used as leguminous cover. On account of its smothering habit it was replaced early in 1940 by *Pigeon pea* and *Tephrosia candida*. Plantains 10′ x 10′.

(iii) *Plantains and Mulch.*—Plantains 10′ x 10′. Trash from the plantains is spread in a ring round the cocoa.

(iv) *Erect legume.* *Crotolaria retusa* and *C. striata* were first sown. *C. striata* was replaced by *C. retusa* in March, 1940. *C. retusa* was replaced, after one re-sowing, by *Leucaena glauca* in 1941.

(*b*) *Permanent Shade*

Samanea saman 50′ x 50′; *Albizzia lebbek* 50′ x 50′; *Tetrapleura tetraptera* 50′ x 50′; *Peltophorum ferrugineum* 50′ x 50′; *Gliricidia sepium* 20′ x 20′; *Leucaena glauca* 10′ x 10′

LAYOUT

The experimental unit for a *temporary shade treatment* is a square ¼-acre plot. The four treatments are randomised within two-acre blocks : there are 16 replicates of each treatment. Each of the six *Permanent Shade treatments* covers two contiguous acre-blocks, i.e. two replicates of each temporary shade treatment. Four replicates of each treatment are under *no shade*.

PLANTING

The whole of the area was cleared of tree and shrub growth, burnt over and hoed. Hedges of *Panax* and *Michelia champaca* were established along exposed boundaries. The planting of covers and shade trees was completed in March, 1939. The first cocoa seedlings were planted (10′ x 10′) in June, 1939. The main planting took place in May, 1940. Five plots situated on swampy land were abandoned and replaced by plots on adjacent land in April, 1940.

GROWTH

Cocoa.—Measurements of growth-rate are being made by the Botanist. Growth in general is only fair : it appears to be least satisfactory in Treatment III (Plantains and Mulch).

Plantains.—Four native varieties were first planted indiscriminately. Three have proved satisfactory and have produced a fair number of stems which have needed periodic thinning. A fourth (Apem) is of taller habit and fails to produce suckers until the comparatively large bunch on the main stem approaches maturity. It has two failings : it is susceptible to damage by storms : no large stem is present to supply shade when the main stem is removed. Plantains alone (III) have given limited bottom protection and have failed to control weed-growth. The useful life of a clump is about three years ; after this time the underground stems become spongy and the plants are easily blown over. New suckers were planted amongst the old stock in March, 1942.

Cassava (I).—The native variety " Ankrah " was first planted throughout. It showed a tendency to " lodge ", and comparative trials have since been made with two Botanist's Mosaic Resistant Selections " Garri " and " Queen ". The first showed early promise. It is, however, late branching : it becomes top-heavy and is easily blown over. " Queen " branches profusely in the young stage and gives a lighter and more even shade : it is the most suitable of the three varieties tried.

The tubers of the first plantings were lifted in 1940 and replaced by fresh cuttings from which no crop is to be taken : treatment of cocoa is confined to ring weeding. Plantains in association with cassava have made poorer growth than on other plots : the growth of shade trees has also been retarded by competition from cassava.

Centrosema (II).—Makes such rapid growth under shade that its control is too expensive. Its removal caused a soil disturbance which has unfortunately nullified any cover effect which might have been expected. *Calopogonium*, whose vigour is reduced by shade, might have been a happier choice.

Pigeon pea (II).—Was easily established under plantain shade. Under shade it is liable to attack by rust and mildew in the wetter months, and makes weak growth : it was necessary to re-sow after two years.

Tephrosia candida (II).—Several sowings were needed to establish *Tephrosia* under plantains. Its early growth, especially in the rainy season, was poor and attenuated. It recovered later and a lower branching habit was induced by pruning : it has been the practice to top trees immediately shading the cocoa at 4 feet and to trim the rest down to 2′ 6″. The trimmings provide an ample mulch and the trimmed trees have given an excellent cover which has been successful in controlling weed growth. It is not likely that *Tephrosia* would have been difficult to establish had it been planted at the same time as the plantains : it is probable that it would be a more effective nurse plant if used alone or with shade trees.

Crotolaria (IV).—Both species proved unsatisfactory because of their short life and their intolerance of shade. *C. retusa* was badly attacked by *Sclerotium rolfsii* in the wet months.

Leucaena glauca (IV).—Under plantain shade this cover made slow growth. It could be easily established if sown at the time the plantains are planted.

Permanent Shade.—The average heights and the areas covered by the shade trees after two and a half years growth were :—

	Height feet		*Shade area sq. feet*	
	Treatment I	*Treatment IV*	*Treatment I*	*Treatment IV*
Samanea saman ...	15·5	19	38	380
Albizzia lebbek ...	19	19	120	300
Tetrapleura tetraptera	9·7	8.5	12·5	50
Peltophorum ferrugineum	20	16	154	380
Gliricidia sepum ...	21	23	110	380
Leucaena glauca ...	20	18	60	150

Heights and shade areas in Treatments II and III are intermediate between those of I and IV.

Saman.—In September, 1942, 13 out of 32 trees were found to have been attacked by stem borers (comparative figures are *Peltophorum* 3, *Albizzia* 2, *Tetrapleura* 1). The trunks were heavily lime-washed to 6 feet from the ground as a control measure. The tree shows marked preference for an open situation (Treatment IV).

Albizzia.—The shade effect is light : the stems are bare, with leaves only at the tips of branches.

Tetrapleura.—This, the slowest grower, has a good branching habit, and may prove useful as a shade tree, particularly when grown in an open situation.

Gliricidia.—Its habit suggests that it would give a better shade effect if planted in quincunx. In October, 1942 the cover was sufficiently established to permit the removal of plantains.

Leucaena.—Visually this has been the most successful shade tree, particularly where combined with open treatment (IV). Its falling leaves and pods provide a regular supply of mulch which seems to stimulate the activity of worms. A heavy crop of *Leucaena* seedlings develops : it is likely that they will be suppressed as the shade effect becomes more intense. Plantains were removed from *Leucaena* plots other than Treatment I in February, 1942. The *Leucaena* population was later reduced by cutting out alternate trees.

Weeds.—Presumably on account of the preliminary hoeing and burning, the herbaceous ground cover is poor in all treatments. A species of *Emilia* is dominant in Treatment I whilst in Treatment III some of the plots are covered with grass (*Paspalum conjugatum*). The growth of cocoyams is poor throughout. It will be of interest

to compare the growth-rate of cocoa on these plots with that in the *Second Progeny Trial* where neither burning nor hoeing was carried out.

Pests.—Damage to cocoa seedlings has resulted from attack by *Sahlbergella* and leaf-eating beetles (*Adoretus spp.*) A count made in September, 1941 showed that *Sahlbergella* damage was lowest and beetle damage highest in Treatment II (Plantains, Tephrosia, Pigeon pea). The association of leaf-eating beetles and *Tephrosia* has been recorded in Nigeria. In Treatment II the association appeared to be closer under Pigeon pea. The incidence of beetles in Treatment III (Plantains and Mulch) was not much lower than in Treatment II.

Second Progeny Trial : Hybrids 8 Acres

The land was prepared by clearing 7½ acres of secondary forest and 1½ acres of cocoa. The older forest trees were felled over the area and in adjoining plots to allow the cocoa to be planted at regular spacing and to obviate damage from falling branches. Younger trees were thinned selectively. All *Triplochitons* and the large *Celtis* and *Terminalia* spp. were cut down. All leguminous trees and most of the saplings of other species were left.

Felled trees were left on the ground. A heavy herbaceous growth (including cassava and cocoyam) has sprung up and appears to provide a complete natural cover. Half the area was planted with *Leucaena glauca* and half with plantains (10′ x 10′) in randomized acre blocks. Cocoa was planted (10′ x 10′) from 1941 onwards. The area was separated from old cocoa by a six-foot clearance and a hedge of *Champac*.

Third, Fourth, Fifth Progeny Trials

See Botany Section (p. 23)

Establishment Trial : Akwadum

The primary object of the trial is the re-establishment of cocoa in an area which has been denuded by Swollen-shoot disease.

Twenty-five acres of derelict farm have been leased at Akwadum, a village in the heart of the main diseased area. The whole of the farm had formerly been under cocoa. When leased (May, 1941) it contained small patches of apparently healthy trees, a forest of dead stumps and a few cleared spaces. Photographs of the site were taken.

The experiment is designed to find out—

(i) whether ring-hedging will hamper or prevent the spread of swollen shoot.

(ii) the relative merits of regular (10′ x 10′) spacing and irregular close spacing (native).

(iii) the relative merits of planted overhead shade and shade provided by the development of native saplings.

(iv) the value of *Erythrina altissima* as a shade tree.

LAYOUT

Ring-hedging.—A single hedge of *Cassia siamea* (3′) encloses a square block of 16 acres. Inside this hedge are concentric double (3′ : 2′) treble (3′ : 3′ : 3′) and quadruple (3′ : 4′ : 4′ : 4′) hedges spaced at successive intervals of 104′. The innermost (quadruple) hedge thus encloses a square block of 1 acre.

Spacing.—The 15-acres outside the central block are divided into 12 one-acre and 4 three-quarter-acre plots. Cocoa in alternate plots (6 one-acre, 2 three-quarter-acre) is planted 10′ x 10′ under plantains (10′ x 10′) *Tephrosia* and *Leucaena* 10′ x 5′). In 6 one-acre plots it is planted irregularly (roughly 5′ x 5′) and in 2 three-quarter-acre plots regularly (5′ x 5′). In these close planted plots plantains and cocoyams are used as nurse plants. All plots are subdivided into $\frac{1}{4}$-acre plots.

OVERHEAD SHADE

Erythrina.—Is planted 30′ x 30′ in the centre acre where cocoa is planted 10′ x 10′ with temporary *Leucaena* shade. All forest trees have been felled.

Samanea saman.—Has been planted 50′ x 50′ over two diagonally opposed $3\frac{3}{4}$-acre blocks of "spacing" plots, from which all forest trees were removed.

Saplings.—Have been left to develop in the remaining two $3\frac{3}{4}$-acre blocks : large forest trees have been removed.

TREATMENT

All cocoa trees were dug out. All specimens of *Cola cordifolia* (alternative host plant of Psyllid) were cut down. Hedges were planted between August and December, 1941. Nurse plants and shade trees had been planted by March, 1942. Cocoa had been sown at stake over the whole area by June, 1942. Germination was good, and the high survival rate through three succeeding months of drought was noteworthy. The policy of planting the cocoa so soon after the nurse crops has so far been justified. Within 19 months of opening up the Station the crop has been well established.

RESISTANCE TRIALS

Roughly 7 acres of land outside the Hedge Trial area are being used to test trees selected for their resistance to Swollen-shoot disease (*see* Botany Section).

REJUVENATION TRIAL

The object of the Trial is to determine the quickest and cheapest method of restoring farms which, chiefly through age and soil exhaustion, are declining in yield and condition.

The selection of a uniform patch of cocoa was not easy. An area of 6 acres was finally chosen to represent the oldest cocoa on

the Station. The number of trees was 2,076 (1941), average age 25 years, girth 21", spacing 13' x 13'. The pod-yields had been 1939, 71,252 ; 1940, 65,760 ; 1941, 60,640 ; a decline independent of annual fluctuation (p. 7).

LAYOUT

Each treatment plot is $\frac{1}{8}$th acre. There are four treatments with 12 replicates of each treatment.

TREATMENTS

I. *Mulch.*—Elephant grass is applied twice yearly at the rate of 1 ton per plot, i.e. 16 tons grass (semi-dry weight) per acre per annum. The first application was made in August, 1941.

II. *Legume.—Leucaena glauca* was broadcast in August, 1941. Growth has been good except under dense shade, where supplementary sowings of *Tephrosia* have been made. This, too, has been difficult to establish.

III. *Coppicing, with Plantain Shade.*—Plantains were planted 10' x 10' in September, 1941. The trees were ring-barked 6" above ground to encourage chupon growth. (Preliminary pollarding trials made (without ring-barking) at heights of 3" to 18" above ground had shown that 6" was the optimum pollarding height).

The trees were coppiced at 6" in April, 1942 and the stumps earthed up. Only 53 per cent of the trees then had chupons. In November, 1942, 22 per cent of the coppiced trees had succumbed. Chupon growth was particularly poor on the older trees, which seemed more susceptible to *Sahlbergella* damage.

Mass pollarding gives little promise of success compared with the slower practice of removing the main stem after a chupon has been nursed to sufficient size.

IV. *Stumping and Replanting under Leucaena Shade.*—The area was stumped in July, 1941, and planted with *Leucaena glauca* (10' x 10'). Seedlings of the Botanist's high-yield selections were planted 5' x 10' in May, 1942.

MANURIAL TRIALS

Complete (NPK) Fertiliser Trial on Average Cocoa

Unit.—Eighteen trees. Average yield of each unit roughly equal to the average for the Station. Individual tree yields are recorded.

Treatments.—P. K. KP. Control. Nitrogen imposed as a half-plot treatment.

N=2 lb. sulphate of ammonia per tree.
P=2 lb. superphosphate per tree
K=2 lb. sulphate of potash per tree
C=No treatment.

Layout.—Latin square 4 x 4. Total 228 trees. A double guard-row of trees is left between treatments.

The choice of site was made difficult by the heterogeneity of the Station cocoa. The trees selected had an average age of 18 to 20 years, girth 14″, spacing 10′ x 10′.

Manures have been applied roughly six months before maturation of the major crop. Litter was scraped up, the manures applied as a surface dressing and the litter replaced. First application March, 1941. Second application May, 1942. Treatment was delayed by the shortage of manures. In the second year half the dosage of superphosphate had to be applied in May, the other half in August.

YIELDS: PODS PER TREATMENT

	Pre-treatment		*Treatment*	
	1939	1940	1941	1942
Control	1,949	1,570	1,672	1,560
K	880	1,411	1,470	1,270
KP	1,146	1,247	1,541	1,510
P	1,332	1,348	1,659	1,738

There is an indication that yield is being improved by phosphatic manuring. The variance due to error is disappointingly large, and the increase is not yet significant.

Comparative Trials of Phosphatic Fertilisers

To determine (i) whether large periodic applications of slowly available phosphatic fertilisers are more economic than more frequent applications of readily available ones, labour of application being a necessary consideration; (ii) the relative merits of basic slag and superphosphate on acid soils.

Unit.—Eighteen trees chosen as in the Complete Fertiliser Trial. Average age 22 years, girth 15″, spacing 10′ x 10′.

Treatment

1. Superphosphate 2 lb. per tree annually
2. Superphosphate 4 lb. per tree every two years
3. Basic slag 2 lb. per tree annually
4. Basic slag 8 lb. per tree every 4 years
5. Rock phosphate 12 lb. per tree every four years
6. Control No treatment

Sulphate of potash, 2 lb. per tree annually is imposed as a half-plot treatment.

Layout.—Four randomised blocks of six plots each.

Manures have been applied at the same time as in the Complete Fertiliser Trial.

YIELDS: PODS PER TREATMENT

	Pre-treatment		*Treatment*
	1939	1940	1941
Control	3,026	2,834	2,360
Super 2	1,899	1,757	1,890
Super 1	1,992	3,960	2,241
Rock phosphate 4	2,316	1,987	2,056
Basic slag 1 ...	2,639	2,530	2,665
Basic slag 4 ...	2,769	2,205	2,698

No significant result was obtained in the first year. Yields for the second year are not yet available.

Complete (NPK) Fertiliser Trial on Young Cocoa

Since no large quantity of uniform young cocoa is available on the Station this trial is being carried out on newly planted cocoa, made as homogeneous as possible by the use of seedlings from two selected trees.

Unit.—Twenty-four trees spaced 5′ x 5′: area 1/32nd acre: arranged in 3 rows of 8 trees, allowing subsequent reduction to 10′ x 10′. 2 rows selection T9: 1 row selection T6 10′ x 5′ alternating with seedlings of mixed progeny.

Treatments.—N : P : K : NP : NK : PK : NPK : No treatment.

N=$\frac{1}{4}$ lb. sulphate of ammonia twice yearly

P=$\frac{1}{4}$ lb. superphosphate twice yearly

K=$\frac{1}{4}$ lb. sulphate of potash twice yearly

Layout.—Eight randomised blocks of eight treatments. Treatments separated by two guard rows. *Gliricidia* was planted as temporary shade in May, 1941. Cocoa was planted out in May, 1942.

BOTANY

(A. F. Posnette)

SELECTION

Yield and quality were the main considerations when selection was begun in 1937. It was later concluded, after a large number of farms in the chief producing areas in the Colony, Ashanti and Togoland had been surveyed for high-yielding trees, that no benefit would result from the improvement of the quality and yielding capacity of planting material unless Swollen-shoot virus and Capsid pests could be controlled. The early selection work was not immediately abandoned, for it appeared then that Swollen-shoot might be localised, and that some of the selections might be high-yielding because of their tolerance to Capsid attack. Since September, 1940, however, selection has been concentrated on a search for trees resistant to Capsids and virus diseases.

Selection for Yield and Quality

AVAILABLE MATERIAL (*a*) *Amelonado Type*

The foundation for a selection programme had been laid by individual tree-recording at Aburi since 1914, at Asuansi and Kumasi since 1919, and at Kpeve since 1928. On the basis of plot yields taken at seven agricultural stations[1] the Amelonado type had been regarded as the most suitable, and records of individual trees had been taken only from plots of this type, which is predominant in West African farms. It must be distinguished from trees with Amelonado-shaped pods which segregate from the Trinitario hybrid types. It breeds true to type and was first thought identical with *T. leiocarpa* Bern : the validity of this name has recently been doubted.[2] Its main characters are :—

(i) *Uniformly High Yield.*—Experiments made at Aburi in 1937[3] showed that the type contains a far greater percentage of self-compatible trees than Cundeamor or Criollo types. The low degree of self-incompatibility in West African cocoa may account for the yields so greatly surpassing those of the West Indies.

(ii) *Uniform Size of Beans.*—Objection to the Amelonado type is usually raised because its bean has neither the plumpness nor the intrinsic quality of the Criollo types. This is counteracted to some extent by its uniformity, for although well below the "fine" types at their best West African cocoa is free from the very small beans segregating from the Trinitario complex. The average Gold Coast bean is only a little lighter than the average Trinidad bean, the relative figures being Gold Coast 426 beans (10·6 pods) per lb. Trinidad 420 beans (12 pods) per lb.

(iii) *Slight Genetical Variation.*—Little variation is noticeable in the field. Trees with unusually large or small Amelonado-shaped pods appear invariably to be segregated from the Trinitario mixture and are usually found in association with other typical segregates. Low variation in the number of pods per tree has been recorded(4)(5). Before a reliable method of selection could be adopted the variation in pod-weight and in bean-number per pod required investigation.

In July and August a detailed survey of the Tafo cocoa was made by counting and weighing beans from a random sample of 10 pods from each of 900 Amelonado trees selected at random: this was repeated in December to show the seasonal trend. The results showed that the mean number per tree remains constant throughout the season, with comparatively little tree to tree variation: the mean pod weight decreases from under 10 to over 11 pods per lb. dry cocoa. This variation is slight compared with Trinidad figures(6), especially when the differences in age, spacing and shade of the Tafo trees are considered. It will also be seen that the trees which carried the heaviest pods in July did not repeat their superiority in December.

	July		*December*	
	Bean No. per pod	*Wet wt. per pod : gm.*	*Bean No. per pod*	*Wet wt. per pod : gm.*
Mean for 900 trees	41·7	116·0	40·9	102·0
Mean for 30 trees with heaviest pods in July	43·4	146·0	40·8	92·0

It is clear that variation in yield of beans between Amelonado trees must depend almost entirely on the number of pods produced—a factor more likely to be influenced by environmental conditions than pod size, and therefore a less reliable basis for selection.

(*b*) *Trinitario* (*hybrid*) *type*

It had been shown(3) that the low plot yields of Cundeamor and Criollo types at Aburi might be partly ascribed to the large number of self-sterile trees. Later yield records confirmed that a few self-compatible trees were contributing a very high proportion of the total yield. It was decided that selection should not be restricted to the pure Amelonado type which, from the breeder's standpoint, shows a depressing uniformity in yield and quality.

The number of self-compatible trees of hybrid type (Cundeamor, Ocumare, Red and Yellow Criollo) on experiment stations was inadequate for selection purposes. A survey of native farms was therefore carried out over the important producing districts in the Colony and Ashanti. The survey revealed an unexpectedly large number of farms with more than 30 per cent Trinitario trees. Some of the trees appeared too old to have sprung from the Trinitario

types introduced from River Estate to Aburi in 1905–09. Types including "Caracas White Cocoa" and "*T. pentagona* white cocoa" were available for distribution at Aburi in 1906 : these early introductions appear to have left their mark.

The yield variation in Trinitario cocoa has been investigated by Pound(6). Variation in the same type introduced from Trinidad appears to be similar on the Gold Coast if due allowance is made for the smaller tree-population.

Whilst Amelonado appears hardier than Criollo, and can be grown under conditions of higher humidity and denser shade without suffering the same damage from canker and pod-rot, it can be expected that some of the hybrids will prove even hardier than pure Amelonado. There is no indication that hybrids on native farms are less suited to soil and climate than Amelonado : compared with neighbouring Amelonado trees of the same age they seem more vigorous growers and less subject to die-back. At Tafo they do not appear to be more susceptible to attack either by *Phytophthora* spp. or *Sahlbergella*. Thus in a comparison of 29 hybrid trees with 29 Amelonado trees drawn at random from the same plots the following figures were obtained :—

Hybrid	Total pods	333	: Diseased	40	: Capsid damaged		68
Amelonado	,, ,,	627	,,	113	,, ,,		81

METHOD OF SELECTION

Instead of fixing a standard which each selection must pass, irrespective of locality, the highest yielding trees have been selected in each plot or farm chosen for observation. This method which ensures that the trees are not concentrated in one particular environment, is the only one applicable to native cocoa farming with its irregular spacing and widely differing degrees of cultivation.

Self-compatibility was made a firm criterion of selection. All provisional selections were tested, and those discarded which failed to set less than 50 per cent of the flowers self-pollinated by hand.

(*a*) *Amelonado*

Since the tree's merit must be judged by the number of pods produced, it is essential to eliminate seasonal variation by obtaining yield records over a number of years. Selection in the Amelonado type was therefore restricted to experiment stations. The number of existing trees for which individual yields had been recorded was :—

Aburi 179 (since 1914) : Asuansi 207 (since 1919) : Kpeve 256 (since 1928). All were of uniform age and regularly spaced. The ten best trees were selected from each station, some being chosen on early, some on recent yields, to eliminate the variation in competition which may have been caused by the death and replacement of neighbouring trees. Seed from 28 of these 30 trees, whose mean yield over the recorded period ranged from 7·0 to 15·2 lb. dry cocoa per annum, has been propagated in the First Progeny Trial.

The exact age of the trees at Tafo is not known. There is probably a close correlation between girth and age, and selections for further recording have been made by classifying the yields of 24,972 trees into 1″ girth classes and choosing the outstanding performers in a given class. The yields of seven such trees are compared below with the mean yield of their girth classes. As the yield of each is three times that of the mean there is statistical reason for supposing genetical difference sufficiently great to off-set the variance due to the irregular spacing both of cocoa and of shade trees.

Selection No.	Girth at 3 ft. (1939)	Mean pods per year (1938–40)	Mean dry cocoa p.a.	Mean yield (pods) of girth class
T3	16″	132	11·43 lb.	35·5
6	20″	178	15·50 ,,	44·5
4	26″	183	15·95 ,,	44·6
9	25″	188	16·32 ,,	58·1
7	24″	205	17·82 ,,	48·1
5	24″	208	18·05 ,,	48·1
8	32″	237	20·64 ,,	70·6

(*b*) *Trinitario* (*hybrid*)

No yield records were available. From all trees (160) at Aburi ; 36 out of 679 at Asuansi ; 46 at Tafo ; 100 from native farms at Akrokerri, Ashanti ; 8 out of 70 at Potroase, yearly records have been taken since 1938. The total number of pods was counted and the bean number determined on a sample of at least 30 pods. 15 selections were finally made.

In scattered native farms, where continuous recording is not possible, pod-counts, pod-weights and bean-counts have been taken in September or October. These counts, while not providing a true estimate of yield, are legitimate for comparison, and clearly indicate any hybrids exceeding the yield of neighbouring Amelonado trees. A number of these native farm selections proved to be self-incompatible. Twenty are included in the Third Progeny Trial.

The 15 continuously recorded selections showed considerable variation. The mean bean number varied from 23 to 42, mean wet weight per pod from 80 to 184 gm. The average yield, expressed as lb. dry cocoa, does not compare favourably with that of the Amelonado selections. True comparison is made difficult by the unknown age factor and the fact that the recording periods are not the same.

PROPAGATION

By Seed.—It was agreed at the Third West African Agricultural Conference that seed only is suitable for supply to farmers. Apart from transport difficulties it is unlikely that farmers will give cuttings or buddings the necessary attention. Seed produced by hand-pollination is being tested in trials designed to eliminate chance causes, such as soil conditions and lack of competition, which may have been responsible for the high yield of the parents.

Whilst nothing precise it known about the inheritance of yield it is expected that some inherently high yielders will produce progeny of a higher average yield than unselected stock.

Hand-selfing is done between March and July. The beans are planted in baskets from September to January and the seedlings kept under *Leuca na glauca* shade until the following April. Shade is then removed and the seedlings planted out during the first rains (May and June). Vacancies are filled during the second rains (October).

First Progeny Trial (*Amelonado*). *See* Establishment Trial p. 11.

Twenty-eight Amelonado selections from experiment stations, one selection from Nigeria, one hybrid from a native farm.

Three self-pollinated seedlings from each parent randomised in a sub-plot with unselected seedlings and buddings from each parent as control : 64 replications of each sub-plot. Spacing 400 per acre. Main planting May, 1940.

Second Progeny Trial (*Hybrids*). *See* p. 14.

Selfed progeny of 35 hybrids, one Amelonado selection.

Seventy-two seedlings of each selection randomised in eight plots of nine trees each. Spacing 400 per acre. Main planting 1942.

Third Progeny Trial. (Rejuvenation Trial p. 14).

Selfed progeny of 13 Tafo, 1 Aburi, 2 native farm selections in randomised plots of 28 trees. Total 1½ acres. Spacing 5′ x 10′. Planted 1942.

Fourth Progeny Trial (*White Beans*).

Progressive planting of progeny of white beans, some of known parentage, some illegitimate. Interplanted with seedlings from purple beans (to be cut out later) to compare growth-rates. Spacing 5′ x 10′. Planted 1941 and 1942.

Fifth Progeny Trial. (Fertiliser Trial on Young Cocoa p. 18.)

Selfed progeny of two Tafo Amelonado selections, alternating with mixed progenies. Spacing 5′ x 10′. Planted 1942.

CLONAL TRIALS

Bud-grafts of all, and rooted cuttings of some, of the selections have been established at Tafo, mainly with the object of increasing the amount of budwoods available. The collection of budwood immediately after a tree had been provisionally selected has saved a number of selections of which the parent has since died of Swollen-shoot or root disease.

Root-stocks have been planted for the establishment of 12 acres of budded clones, distributed in randomised plots of 16 trees. Whilst their chief purpose is seed production of any selection proved worthy of distribution, the behaviour of individual clones with regard to yield and disease and pest resistance will be of interest. It is realised that the distribution of clonal material may become necessary, especially if selection produces clones resistant to Swollen-shoot virus and Capsid attack.

Selection for Capsid Resistance

Field observations have shown that whilst *Sahlbergella theobroma* usually feeds on the shoots of seedlings and trees under six years old, damage on mature trees being confined to pods, *S. singularis* shows a preference for the shoots of mature trees. When, however, both species were offered free choice of young and old shoots under laboratory conditions no discrimination was shown. A similar lack of discrimination was shown when bugs were offered the choice of shoots from susceptible and apparently "immune" trees(?). The experiment suggested that the preference shown in the field was not influenced by sap palatability and indicated little prospect of finding unpalatable trees.

A seemingly tolerant tree has been under observation at Asuansi since June, 1941. Attack by *Sahlbergella* has been negligible whilst neighbouring trees have been so badly attacked that some have been killed. Budlings at Tafo have likewise escaped attack until infested by hand with nymphs of *S. theobroma*. As a result of these insect punctures, lesions developed but were localised, and no defoliation or dieback ensued. The selection (S.C.1) is being propagated as extensively as possible, and a field experiment has been laid down to compare the resistance of budded plants of S.C.1 with the susceptibility of the Amelonado variety.

Degrees of tolerance have been observed among the "yield and quality" clones budded at Tafo. In order to obtain an accurate estimate of the order of tolerance involved, an experiment has been designed in which randomised plots, each of 14 budlings, of 50 hybrid selections are laid down in triplicate.

Selection for Swollen-shoot Resistance

In the radial form of spread of Swollen-shoot (*see* p. 58) healthy trees with their foliage in contact with that of an infected tree will, normally, become infected before more distant trees. Occasionally, however, a contact tree remains in full leaf, and continues to survive even after the other trees in the farm are reduced to decaying stumps. These sole survivors must either have escaped infection by sheer luck, or else be resistant.

The heavily infected area bounded by Suhum on the west, Tafo on the north, the Scarp on the east and Koforidua on the south, was combed for resistant trees in 1940–41. Three hundred and twenty-eight trees, distributed in 18 villages, were selected for observation. In some, signs of infection could be seen: no survivors with swellings were selected, but a few with only mild chlorosis were kept under observation. Selections have been inspected three times yearly and abandoned if severe dieback has developed. Thirty-seven selections have since been made on recently denuded farms.

At the end of 1941, 152 of the original 328 selections remained healthy; most of these were grafted with infected scions to test their resistance, and at the end of 1942 only 54 remain without symptoms. Some of these may prove to be tolerant. Selections are only abandoned when dieback becomes serious.

These selections are being tested for resistance at Akwadum, where over 3,000 seedlings from 113 "resistant" selections have been planted as root-stocks. After budding, both stock and scion are encouraged to grow, so that when the plant is infected by grafting the resistance of both stock and scion may be judged.

This programme has not, so far, yielded any highly resistant clones, but quite promising signs of tolerance have been noted. No. SS. 167, for instance, has been infected at least since July, 1941, but both the parent tree and budlings from it show no symptoms except mild mosaic on a few leaves. This selection is being propagated as extensively as possible.

A new development during 1942 has been the testing of large numbers of hybrid types. Thirty of the most vigorous Aburi trees are being propagated for testing at Akwadum. At Wiawso and Peki (where the disease is already present in native farms) whole plots of Cundeamor and Ocumare trees have been infected by grafting—a total of 2,095 trees, which should give a good indication of the range of susceptibility in the cocoa already introduced from Trinidad.

The most promising hybrid so far tested is a seedling from a high-yielding selection at Kumasi. This seedling was infected by grafting in May, 1942, and has so far shown no sign of infection, although other seedlings infected simultaneously with the same budwood have now reached the defoliation stage of the disease. This selection, AH22, has been propagated by budding for further tests. The parent selection K5 is also being tested for resistance.

PROPAGATION

BUDDING

In the establishment of the first clonal plots it was necessary to bud on to such stocks as were then available: these had been irregularly planted in native fashion. Two acres planted at stake in 1941 are now ready for budding: a further nine acres were prepared for planting stocks in 1942.

Budding has also been carried out on suckers produced by the ring-barking and subsequent pollarding of old trees. Ninety-seven trees have been budded successfully. Only 12 per cent of the trees pollarded in May, 1941, have since died.

A farm has been acquired near Bekwai, on which it is intended to establish clones of the yield and quality selections. Bekwai was chosen as a convenient point on the railway in an area presumed to be free from Swollen-shoot. A survey of the farm in March, 1942, disclosed about 1,000 seedlings suitable for budding; of these 344 have now been budded, and establishment is proceeding satisfactorily.

CUTTINGS

No attempt has been made to root cuttings on an extensive scale, but two small-scale tests of the etiolation method have indicated that tying black cloth round the shoot for a month before severance induces more rapid and profuse rooting. Whether it is more than a marcotting effect is not known.

TWINNING

A preliminary note on experiments made at Tafo in the twinning of cocoa seedlings by a procedure similar to that found successful with Hevea in the East has been published(8). Using an improved technique losses have been only about 3 per cent.

NATURAL POLLINATION

Accounts of experiments carried out between May, 1938 and October, 1941 have been published(9)(10). The following conclusions were reached :—

Pollination of the Amelonado type of cocoa is effected by insects.

The percentage number of flowers pollinated is dependent on the size of the insect population. During the profuse flowering period about 10 per cent of the flowers are pollinated : in low flowering periods, when insects are able to visit nearly all the flowers, the percentage of pollinated flowers is much higher. Seventy-nine per cent of the flowers on 64 trees were pollinated between 7th November, 1939 and 5th February, 1940.

Ants are responsible for about half the pollination effected : unidentified flying insects, not of nocturnal habit, are responsible for the other half. Aphids are not pollinators of any significance.

The ant *Crematogaster* (Sphaerocrema) sp. No. 1267 is an important pollinating agent : a closely related ant *Crematogaster* (Acrocoelis) sp. No. 1286 is also operative.

The inactivity of these pollinating ants during periods of low humidity (March) probably accounts for the low percentage pollination then recorded.

During 1942 an experiment has been in progress at Aburi to investigate the distance over which cross-pollination occurs during the whole flowering season. The pollen of a single red-podded tree is being traced through the entire crop of two rows of surrounding yellow-podded trees, using the inherited red axil-spot on the seedlings as an indicator. The result of this experiment should help to determine the optimum plot size and lay-out for seed-producing clones.

Colchicine

Preliminary experiments have been carried out to ascertain the best method of treating cocoa seedlings with colchicine to induce polyploidy. The seedlings have not been examined cytologically, but there are morphological indications that polyploidy has been induced by 25 per cent colchicine solution applied to the growing point.

SHADE EXPERIMENTS

GROWTH FLUSHES

The growth flushes of the cocoa tree have been given considerable importance in their relation to attacks by disease (Witches' Broom in Trinidad) and insect pests (Thrips in Trinidad and *Sahlbergella* spp. in West Africa).

In Trinidad the opinion has been advanced that the reduction of shade decreased the incidence of Witch Broom by the reduction of humidity and possibly the more rapid hardening of the flushes[11]. No mention is made of any greater flushing in unshaded areas, except in relation to Thrips attack which caused heavy flushing[12], unshaded cocoa being more liable to attack. Observers in the Gold Coast have concluded that unshaded cocoa flushes more than shaded cocoa, thus rendering the former more liable to *Sahlbergella* attack. Cobley[13] has shown in Trinidad that shade greatly increases the flushing of young cocoa.

The periodicity and degree of flush have been investigated in relation to shade conditions and *Sahlbergella* attack to find whether heavy flushes are the result (as with Thrips in Trinidad) or the cause of *Sahlbergella* damage.

During 1938–39 observations were made daily when flower counts were taken on 64 trees scattered over Tafo station. Estimation of leaf flush was made according to arbitrary standards :—

0 = no flushing
1 = 1 to 6 twigs flushing
2 = more than 6 twigs, less than $\frac{1}{2}$ of canopy
3 = $\frac{1}{2}$–$\frac{3}{4}$ canopy flushing
4 = general flush with total regeneration of the canopy.

The daily figures were converted to a weekly basis (by taking the mode for the week), probably reducing the error inevitable with such an arbitrary scale. For subsequent analysis 3 and 4 were combined as so little " general flushing " was observed.

The trees used were of Amelonado type, with a uniform leaf pigmentation. The degree of colour developed depends greatly on exposure to sun, however ; heavily shaded young leaves never develop the pink colour, which develops roughly in inverse proportion to the degree of shade. Hence the pink colour is not a reliable standard for comparing the flush of plots under different conditions, but actual leaf counts must be taken.

DISTRIBUTION

Distribution curves showing the degree of flush for each week were prepared. They showed that the majority of the trees were flushing at degree 1 for most of the year, though there was a marked resting period following the lesser dry season (July-August) and a period of heavy flushing in December. There were *five peak periods of flush, independent of shade conditions*. A similar distribution has been recorded in subsequent years, and its dependence on climatic factors is being investigated.

SHADE EFFECT

The flushing of 12 trees on $\frac{1}{4}$-acre plots with no medium or low forest trees has been compared with that of 12 trees on plots containing more than six medium or low trees.

The mean numbers of weeks during which a tree recorded a particular degree of flush were :—

Flush Index	0	1	2	3	4
Unshaded	12·5	25·7	6·2	2·1	0·5
Shaded	15·8	21·8	6·5	2·4	0·5

Analysis of the distribution shows that there is significantly more flushing on the unshaded plot. This is entirely due to the number of weeks in which the trees flush at degree 1 or not at all, for significance is lost if degrees 1 and 2 are grouped together.

SHADE AND SAHLBERGELLA

In 1939–40 measurements were made on three heavily-shaded and three completely unshaded plots, roughly $\frac{1}{16}$ acre each. They were comparatively free from *Sahlbergella* damage when chosen in May, 1939, though adjacent to badly damaged areas from which it was thought they would become infected : subsequent damage was less than that on most Station plots. Evaporation on the shaded plot at canopy level was roughly $\frac{3}{4}$, light intensity $\frac{1}{10}$ that of the unshaded cocoa.

Weekly flush was measured over a period of 45 weeks by the method previously used. A similar index was used for *Sahlbergella* attack. There is a delay of about two weeks between attack and visible extensive damage : this lag was not adjusted. The production of a heavy flush when damage was visible was taken to indicate a recovery from attack.

To obtain an estimate of flushing in the absence of *Sahlbergella* six trees enclosed in cages of baft, muslin and mosquito-netting were used. The relative evaporation rates determined by Piche hygrometers were :—

Baft cage 1·00 : Shaded plot 1·57 : Muslin cage 1·62 : Netting cage 1·86 : Unshaded plot 2·08.

Despite the difference in humidity no significant difference in the periodicity or degree of flush was found between the three types of cage. Flushing in the cages was accepted as the normal flushing routine in the absence of *Sahlbergella*.

There was no significant difference in *Sahlbergella* damage on the three shaded plots compared with the three unshaded plots.

Sahlbergella Index	0	1	2	3–4	*Total weeks*
Shaded Plots ...	80	51	4	—	135
Unshaded Plots ...	65	51	13	6	135

Hence the six plots have been grouped together (Open) and compared with the six caged trees.

Flushing Index	0	1	2	3–4	*Total weeks*
Open	96	64	53	57	270
Caged	92	103	46	29	270

Here the difference is significant at 0·1 per cent ($f=3x^2=18·80$) the main difference lying not in the number of weeks with or without flush but in the highly contrasting numbers for indices 1 and 3–4. *The exclusion of Sahlbergella therefore allows a greater frequency of small flushes to appear, though fewer are prolonged into main flushes.*

Comparing shaded and unshaded plots there is a significant difference ($x^2=49·49$. f=3. sig. at 0·1 per cent) largely due to the relative frequencies of (i) weeks without flush and (ii) weeks with high index flushes. In the first respect the tendency is similar to that observed in the previous year : the difference is much greater.

Flushing Index	0	1	2	3–4	*Total weeks*
Shaded	74	30	14	17	135
Unshaded	22	34	39	40	135

Further analysis showed that whilst *total damage* due to *Sahlbergella* is *higher on unshaded plots, severe damage* is significantly *greater on shaded plots*. In contrast to shaded plots, unshaded plots showed no significant depression of flushing associated with *Sahlbergella* damage.

ARTIFICIAL SHADE

During 1940–42, the flushing on the three shaded and three unshaded plots was compared with that on plots artificially shaded with mats. Artificial overhead shade reduced flushing in the same way as does natural shade i.e. in degree, but not in frequency. The most striking effect of the artificial overhead shade has been to destroy the canopy by stimulating chupon growth instead of fan flushes. As a result, trees under the artificial shade erected in July, 1940, have the upper part of their trunks, and their main branches, arrayed with chupons. This may account for the slightly greater damage caused by *Sahlbergella*, as compared with unshaded controls.

Artificial lateral shade appeared to stimulate flushing in July and August, but this was probably due to root disturbance or pruning when the screen was erected. Otherwise shaded and unshaded plots flushed alike.

ARTIFICIAL SHADE AND YIELD—(*see* p. 10)

Weekly counts of flowers, sets and cherelles have been made on five trees chosen at random in each of the shaded plots and controls.

	Flowers			*Sets*		
Treatment	*Total* 1942	1942	% *Change*	*Total* 1941	% 1942	*Change*
Lateral ...	6616	1274	–80·5	827	635	–23·0
Control ...	2266	1691	–25·4	563	895	+59·0
Overhead I ...	619	488	–25·0	341	232	–32
Control ...	2810	1066	–62·0	834	495	–40·5
Overhead II ...	6577	583	–91·0	621	288	–53·6
Control ...	2174	750	–65·5	651	354	–45·5

	Cherelles				
Treatment	*Total* 1941	1942	% *Change*	*Peak Week* 1941	1942
Lateral	5874	5279	–10·1	389	319
Control	5901	7565	+28·2	423	656
Overhead I	1145	940	–17·9	79	40
Control	5907	5131	–12·9	355	205
Overhead II	3054	2268	–25·7	184	130
Control	4894	3997	–18–3	332	192

No definite conclusions can yet be drawn. Overhead shade appears to be reducing yield by increasing cherelle wilt, but the 1942 yields were lower than those for 1941 on control plots also. Compared with the controls, lateral shade appears to exert an even greater influence than overhead shade in reducing flowering and setting, and increasing cherelle wilt. To confirm this, however, figures are required over a long enough period to eliminate seasonal variations.

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CHEMISTRY

(M. Greenwood)

ENVIRONMENT

Traditional estate practice in the older cocoa-growing countries is directed to the reduction of extreme fluctuation in the balance between the evaporating power of the air and the moisture-supplying power of the soil. Little knowledge was available to show what measure of reduction, if any, were needed in Gold Coast farms, knowledge made the more desirable by the extensive planting of shade trees which had been carried out in accordance with recommendations made by Dade(2). There was obvious need for environmental studies similar in scope to the early Trinidad investigations(1).

From 1936 onwards measurements of air evaporating power had been made by means of Piche evaporimeters at an increasing number of observation plots throughout the cocoa belt. From the beginning of 1940 comparative measurements of evaporation and radiation above and below the canopy, air and soil temperatures, relative humidity, soil moisture and light intensity have been made at Tafo on plots under heavy forest shade and under no shade. Since August, 1940 similar records have been taken on plots under artificial shade.

The data have been compared with values obtained on a good Trinidad estate. There is no suggestion that the Tafo environment is less suited to cocoa than that of the Trinidad estate : the evaporation rate is lower throughout the year whilst the range of available soil moisture is the same. Since the Tafo evaporation rate is close to the mean rate for the cocoa belt, and the soils are of the type most widely distributed through the belt, there has obviously been no serious local deterioration of environment.

Evaporation

The relation between the transpiration rate and the evaporation rate from water-surfaces (atmometers) of various types has been investigated by Briggs and Shantz(3) and others. Agreement is good in environments where air-movement is fairly constant, a condition obtaining within the closed atmosphere of the average cocoa farm. Macdonald(1) has shown the value of the Livingston atmometer in his researches on the ecology of Trinidad cocoa, and has measured the degree of correlation between evaporation and climatic factors such as relative humidity, sunshine and wind in different eco-climates. Atmometers have the virtue of presenting a cumulative record: they are particularly valuable for collecting data from sites which can be visited only infrequently.

Livingston atmometers have been used at Tafo to obtain figures directly comparable with the Trinidad records. These instruments need delicate handling and periodic correction. Piche evaporimeters have been preferred for use on observation plots, where they are often in the hands of untutored observers.

COCOA BELT *v.* TAFO

Piche hygrometers have been in operation on a number of farms since 1936. They are suspended at a height of 5 feet at a point half-way between the trunk of the tree and the periphery of a cocoa canopy considered normal for the area. A greased cone is fitted to the suspending wire to prevent the passage of insects to the evaporating surface of absorbent paper. Readings are usually made twice weekly : the paper is changed at least once weekly.

From 1939 onwards records have been taken at the following stations :—

Ashanti : Amoyu ; Anwie Nkwanta ; Asuefu ; Effiduasi ; Nkawe ; Ntonso ; Mbeim ; Senchi.

Eastern Province : Aburi ; Akodum ; Dawa Zutchoom ; Densusu ; Nankesi ; Okorase ; Suhum ; New Tafo.

Central Province : Asuansi (2 plots).

Values obtained from shaded and unshaded cocoa at Tafo are compared below with the mean value for the 17 stations. The mean value for the three stations Nankesi, Densusu and Suhum has been taken to represent the evaporation rate in the original swollen-shoot area.

The years 1941 and 1942 are of particular interest. The early dry season (harmattan) was unusually severe in 1941 (Total rainfall 1st December, 1940 to 19th February, 1941, 1·3 inches) and mild in 1942 (rainfall for same period 9·3 inches). The late dry season in 1942 (rainfall 16th July to 21st September, 1·3 inches) was one of the driest on record (rainfall over same period 1941, 8·2 inches).

SUB-CANOPY EVAPORATION : PICHE HYGROMETER MLS. PER DAY

1941	Mean 17 Stations	Swollen-shoot (Mean 3)	Tafo	
			No Shade A6·2	Shade E1·1
January	1·55	1·48	1·44	1·20
February	2·13	2·16	2·46	1·84
March	2·48	2·48	2·79	1·84
April	1·63	1·91	1·68	1·06
May	1·20	1·68	1·28	0·90
June	1·00	1·24	0·98	0·67
July	1·34	0·96	0·79	0·57
August	0·81	1·27	0·85	0·57
September	0·91	1·20	1·00	0·63
October	0·91	1·00	0·90	0·64
November	1·06	1·30	1·32	0·95
December ...	1·07	1·38	1·05	0·88
Average	1·34	1·49	1·38	0·98

SUB-CANOPY EVAPORATION: PICHE HYGROMETER MLS. PER DAY—contd.

1942	Mean 17 Stations	Swollen shoot (Mean 3)	Tafo	
			No Shade A6·2	Shade E1·1
January	1·57	1·50	1·49	1·21
February	1·98	1·79	1·89	1·64
March	1·94	1·79	1·63	0·92
April	1·56	1·78	1·38	0·85
May	1·06	1·07	0·78	0·47
June	0·83	0·84	0·86	0·59
July	1·00	1·02	0·86	0·56
August	1·15	1·28	1·15	0·86
September	1·25	1·59	1·40	0·81
October	1·06	1·15	1·16	0·79
November	1·19	1·11	1·47	1·05
December	1·27	1·24	1·65	1·26
Average	1·32	1·36	1·31	0·92

It will be seen that the evaporation rate on unshaded cocoa at Tafo is close to the mean for the cocoa belt : under heavy shade the rate is two-thirds that of the mean. Similar figures were obtained in 1939 and 1940.

The rate for the Swollen-shoot area is higher than the mean in 1941. It will be noticed that the main divergence from the Tafo rates occurs in the wetter rather than the drier months suggesting that the higher values may result from a poorer canopy. Readings made at Tafo under four unshaded plots of cocoa of varying age have given annual means ranging from 1·18 to 1·32. Corrections to outstation readings are being applied by assessing the canopy density by the measurement of light intensities.

TAFO *v.* TRINIDAD

To obtain close comparison with the Trinidad results atmometers have been mounted on reservoirs of the same type and dimensions used by Macdonald. This was made possible by Professor Hardy's kindness in forwarding a specimen set-up.

SUB-CANOPY

Instruments were placed 5 feet above ground half-way between the trunk and the fringe of the canopy. Results obtained from March, 1940 to February, 1942 are compared below with sub-canopy readings made in Trinidad between March, 1931 and February, 1933.

SUB-CANOPY EVAPORATION: LIVINGSTON ATMOMETER: MLS. PER DAY

	Tafo				Trinidad Torrecilla Good site	
	1940–41		1941–42			
	Shade E1·1	No shade A6·2	Shade E1·1	No shade A6·2	1931–32	1932–33
March ...	6·3	9·1	9·4	12·4	16·3	11·2
April ...	5·9	8·1	4·9	7·2	15·7	8·6
May ...	3·7	5·7	4·2	5·6	14·3	6·5
June ...	1·7	3·1	3·0	4·2	8·9	6·9
July ...	2·5	3·7	2·4	3·4	4·7	7·4
August ...	2·3	3·4	2·5	3·5	6·0	5·3
September	2·9	4·4	2·7	4·1	7·4	7·0
October	3·5	4·6	3·0	4·5	4·6	7·8
November	3·9	4·7	4·3	6·2	3·7	8·9
December	4·9	5·4	4·0	5·2	2·2	6·3
January	5·4	6·8	6·3	6·8	7·3	9·9
February	9·6	11·6	7·0	7·6	11·9	14·9
Average	4·4	5·9	4·5	5·9	8·6	8·4

It will be seen that the average annual evaporation on the unshaded Tafo plot is little more than two-thirds that of the Trinidad field. Evaporation during the exceptional dry season of 1941 is comparable with that during the Trinidad dry season of 1932 : it is much lower than during the Trinidad dry season of 1931. Only in one month (December 1931) is the Trinidad evaporation rate lower than the Tafo rate.

SUPER-CANOPY *v.* SUB-CANOPY

Macdonald gives records taken in 1931 at three heights : " Top, Mid and Lower Canopy strata." The " mid " readings are not significantly different from the " lower " ones. Measurements have been made at Tafo at the top of the canopy in naturally and artificially shaded plots and unshaded controls. Readings for the months when records were collected from all plots are compared below with Macdonald's figures :—

EVAPORATION: LIVINGSTON ATMOMETER: MLS. PER DAY

	Tafo			
	Natural shade E1·1		No shade A6·2	
	Canopy	Ground	Canopy	Ground
July, 1941	3·2	2·4	5·1	3·4
August	3·0	2·5	4·7	3·5
September	3·4	2·7	5·4	4·2
October	3·9	3·0	6·0	4·5
November	5·7	4·3	7·8	6·2
December	5·5	4·0	6·2	5·2
January, 1942	7·5	6·3	7·8	6·8
February	8·4	7·0	8·8	7·7
March	7·0	5·9	9·0	8·2

EVAPORATION: LIVINGSTON ATMOMETER: MLS. PER DAY—contd.

	Tafo				Torrecilla	
	Artificial shade		No shade A6·1		1931	
	Canopy	Ground	Canopy	Ground	Canopy	Ground
July, 1941	6·6	3·0	7·0	3·6	7·0	4·7
August	7·2	3·1	7·9	3·4	9·0	6·0
September	7·9	3·7	8·7	4·1	14·6	7·4
October	8·7	3·8	9·9	4·4	10·8	4·6
November	11·0	5·4	11·7	6·3	9·4	3·7
December	9·4	4·6	10·7	5·3	10·9	2·2
January, 1942	10·3	6·2	12·6	7·1	10·5	8·5
February	11·2	7·0	13·8	8·1	11·8	10·3
March	12·4	7·2	13·5	8·9	17·5	16·3

The *super-canopy* readings on the four plots show a clear gradation. In E1·1, with heavy overhead shade, the evaporation rate is slightly less than at ground level on the unshaded plots A6·2 and A6·1. The atmometer in A6·2 is level with the top of the canopy: it is partially shaded by the canopies of taller trees which have grown up round it. In Artificial Shade the instrument is level with, not under, the mat and receives only slight lateral shelter: in no shade A6·1 it hangs clear of the canopy and is fully insolated.

The Torrecilla readings for March, April and May, 1931 (average 17·4) are higher than any recorded at Tafo. In the 1941 dry season the highest super-canopy rate on A6·2 was 14·9 mils. for the week ending 18th February. Readings at 5 feet above ground have been made on a fairly *open site* (offices) since June, 1941. The highest reading so far obtained was 18·4 during November, 1941.

From the *sub-canopy* readings it will be seen that the rates on the two unshaded plots are similar: that the artificial shade has brought down evaporation to a point halfway between that of the forest-shaded and non-shaded plots in the wet months and close to that of the naturally shaded plot in the dry season (this is true of comparative records extending over two years).

RELATIVE HUMIDITY

Continuous records of Relative Humidity have been taken by Edney recording hygrometers. Monthly means of the Minimum Relative Humidity (which is usually reached about 2.0 p.m.) are compared below with screen measurements made at 3.0 p.m. from spot readings of wet and dry bulb thermometers.

MINIMUM RELATIVE HUMIDITY

	Screen 3.0 p.m.	Natural shade E1·1	No shade A6·2	Artificial shade I	No shade A6·1
April, 1941	60·1	73·6	61·7	65·1	62·2
May	66·2	74·0	63·0	65·4	64·9
June	72·6	78·5	69·4	71·1	68·5
July	73·9	81·0	74·3	75·5	71·8
August	71·2	80·3	75·7	78·4	73·9
September	69·3	77·2	68·1	67·1	66·9
October	69·5	75·4	65·7	71·4	64·8
November	60·8	71·6	61·1	64·2	59·8
December	60·6	73·0	61·9	70·6	62·5
January, 1942 ...	55·5	65·9	58·5	61·3	57·9
February	55·5	50·2	48·0	51·6	49·0
March	56·6	55·8	52·7	56·2	52·9

Readings on the two *unshaded* plots are not significantly different. They are slightly higher than screen readings during wet months and slightly lower during dry months. *Artificial shade* has only small effect during the wet months: in the dry periods it has an effect comparable with that of *natural shade* (compare its effect on evaporation).

The range of relative humidities is similar to that recorded in Trinidad.

EVAPORATION *v.* MINIMUM RELATIVE HUMIDITY

Trinidad

Macdonald has shown that there is a high degree of correlation between Sub-Canopy Evaporation Rate and Minimum Relative Humidity. From *monthly* averages extending over a period of three years he obtained the following values :—

Good site (*Torrecilla*). r = —·947. Regression coefficient of *Evaporation* on *Minimum Relative Humidity* = 0·53.

Bad site (*Las Hermanas*). r = —·918. Regression coefficient of *Evaporation* on *Minimum Relative Humidity* = 0·47.

Tafo

From 51 pairs or *weekly* readings the following values were obtained :—

*Natural shade E*1·1. r = —·959.
x = 25·0–·257Y ± 0·49 (probable error).

*No shade A*6·2 r = —·933.
x = 25·3–·296Y ± 0·77.

(where X = daily evaporation in mils and Y = Minimum Relative Humidity).

The degree of correlation is of the same order as that obtained by Macdonald: it is higher on the shaded plot. The regression coefficients are, however, very much lower.

Under Tafo conditions fluctuations in Relative Humidity produce a smaller change in the evaporation rate than that produced on the Trinidad estates. It seems certain that air movement is much greater in the Trinidad fields than at Tafo. Unfortunately no comparative data are available. Under present circumstances it has not yet been possible to obtain or devise instruments capable of detecting any difference in wind velocity in shaded and unshaded plots: cup anemometers have been tried unsuccessfully.

EVAPORATION *v.* 3.0 p.m. RELATIVE HUMIDITY

It would be an obvious advantage if the evaporation rate could be estimated from standard meteorological data. The most hopeful is a spot reading of relative humidity taken near to the time when minimum values are usually registerd.

Macdonald found that 2.0 *p.m.* spot readings are a fair guide to average relative humidity ($r = +\cdot 900$) which is itself fairly closely correlated ($r = -\cdot 895$) with evaporation.

Correlations of the same order were obtained at Tafo between sub-canopy evaporation and 3.0 *p.m.* readings of Relative Humidity.

Shaded $E1\cdot 1$. $r = -0\cdot 829$
$x = 21\cdot 83 - \cdot 266Y \pm 0\cdot 97$.

Unshaded $A6\cdot 2$. $r = -0\cdot 782$
$x = 25\cdot 55 - \cdot 301Y \pm 1\cdot 26$.

The 3.0 p.m. readings are therefore only a fair guide to the evaporation rate. They are particularly liable to be influenced by showers, which cause a rapid fall in dry bulb temperature. Thus on 26th May, 1940, a shower between 2.0 and 3.0 p.m. brought down the dry bulb temperature from 90°F. to 78°F. in a few minutes and caused a difference of 34 between 3.0 p.m. reading (94) and the minimum humidity (60). There were three instances of similar showers between 2.0 and 3.0 p.m. in the same week.

Air Temperatures

Reading thermometers of the bi-metallic strip type have been in use on naturally shaded and unshaded plots since April, 1940 and on the artificially shaded plot and control since June, 1941. The instruments are checked by readings of maximum and minimum thermometers made twice weekly.

Natural shade causes a pronounced reduction in the daily temperature range. The shaded plot registers maximum temperatures 1° to 4°F. lower, and minimum temperatures 1° to 3°F. higher, than the unshaded. The average diurnal ranges are :—

Shade	Dry months	16·7°F.	Wet months	9·7°F.
No shade	(Feb. March)	22·1°F.	(July August)	11·3°F.

The actual temperatures may be calculated from the screen temperatures given under Meteorology, since the minimum for the shaded plot is equal to the screen minimum.

Maximum temperatures are recorded round about 2.0 p.m. on fine days. Minimum temperatures are usually reached at 7.30 a.m. on the unshaded plot and at 8.0 a.m. on the shaded plots.

Artificial shade depresses the maximum by 1° to 3°F. It has no effect on minimum temperature. Average daily ranges are :—

Artificial shade	Dry months	15·8°F.	Wet months	7·6°F.
No shade ...	(Feb., March)	18·9°F.	(July, August)	8·8°F.

Soil Temperatures

AIR TEMPERATURE *v.* SURFACE SOIL TEMPERATURE.

The daily range of soil temperature has been measured by maximum—mininum thermometers buried at 3″ on the shaded and unshaded plots. The mean surface soil temperature was found to be lower than the mean screen temperature by the following numbers of degrees :—

May–August 2·1°F. : September–November 3·4°F. : December–April 4·2°F.

The *annual range* of surface temperatures in 1940–41 was from 73·4°F. (August) to 77·0°F. (March).

The mean *diurnal range* varied from 1·5°F. (August) to 4·0°F. (March).

SURFACE *v.* SUB-SOIL

Measurements by enclosed mercury recording thermometer at 3″, 6″ and 12″.

Mean Temperature.

6″ less than 3″ by about 0·4°F. throughout year.
12″ not measurably different from 6″.

Diurnal Range.

3″ variable 1·5° to 4·0°F. Minimum 7.0 a.m. Maximum 3.0 p.m.
6″ variable 0·7° to 2·1°F. Minimum 8.0 a.m. Maximum 5.0 p.m.
12″ variable 0·3° to 0·7°F. Minimum 10.0 a.m. Maximum 8.0 p.m.

SHADE *v.* NO SHADE

No difference was detectable by using maximum-minimum thermometers buried at one point on each plot. Noon temperatures were later taken at 3″ and 6″ at nine points in each of the plots.

Natural shade temperatures were from 0·2°F. (July) to 0·9°F. (March) lower than unshaded temperatures both at 3″ and 6″.

Under *artificial shade*, where the soil is of similar type to the control, the shaded plot was from 0·5°F. (October) to 1·5°F. (January) lower than the control at both 3″ and 6″.

Light Intensity

Measurements of light intensity have been made between noon and 2.0 p.m. to assess the effect produced by natural and artificial shade. The illumination produced on a white card held in nine positions on each plot was measured by a photo-electric cell: readings were taken monthly throughout the year. Mean annual readings are expressed below relative to Open Noon Sky = 100.

Natural shade E1·1	Above canopy	8·0	Below canopy		0·7
No shade A6·2	,, ,,	—	,, ,,		3·5
Artificial shade	,, ,,	13·2	,, ,,		0·6
	(under mat)				
No shade A6·1			,, ,,		1·9

The mat therefore reduces light intensity in the same degree at natural shade. The monthly readings show that whilst the mat exerts a constant effect the shade effect of forest trees is greatly reduced in the dry season. (Compare effects on evaporation and humidity).

Soil Moisture

Natural shade *v.* no shade

Weekly determinations of gross soil moisture at 0–6″ and 6–12″ have been made since March, 1940 on composite soil samples taken from nine points in naturally shaded plot E1·1 and in unshaded plot A6·2. Available soil moisture, obtained by subtracting the wilting coefficient from total moisture, has been graphed against rainfall. The shaded plot has consistently contained a higher percentage of available moisture than the unshaded plot. The difference cannot wholly be ascribed to shade effect, as the water-table is higher on the shaded plot. The figures are of value in connection with measurements of the periodicity and intensity of flush made by the Botanist on these plots.

Artificial shade *v.* no shade

In these plots, which are on the same soil type and at the same level above the water-table, there is marked conservation of soil moisture in the shaded plots during dry periods. Significant results were recorded for sets of eight samples taken in January–March, 1941. Gross moistures were :—

	Shade	*No shade*	*S.E. of difference*
30th January ...	7·99	4·15	±0·93
20th February ...	6·56	4·62	±0·39
21st March ... (after rain)	10·86	6·86	±1·15

Similar results were obtained by means of tensiometers (Rogers). During wet periods there was no significant difference other than a lag on the shaded plot in response to heavy showers.

TAFO *v.* TRINIDAD

It is of interest to see whether the higher evaporation rate in the Trinidad fields is balanced by a higher content of available soil moisture.

Minimum monthly values of 1·7 per cent and 2·2 per cent were recorded in the surface six inches of Torrecilla and Las Hermanas estates respectively in May, 1931. *Maximum* percentages in 1931 were 32 per cent (Las Hermanas) and 24 per cent (Torrecilla).

A close approach to the wilting point has been recorded at Tafo only once. On 17th February, 1941, the available soil moistures on the unshaded plot A6·2 were :— 0–6″ 0·6% : 6–12″ 1·7%. Corresponding values for the shaded plot E1·1 were :— 0–6″ 4·8% : 6–12″ 4·9%. The next lowest percentage of available moisture was recorded after the exceptional minor dry season of 1942 when figures for unshaded plot A6·2 on 31st August were :— 0–6″ 4·4% : 6–12″ 5·0%.

Maximum soil moisture recorded in July and October have varied from 17 to 23 per cent. There appears to be little difference in the range of available soil moisture in the two countries.

The Tafo soils are much lighter than those of the two Trinidad fields, wilting coefficients ranging from 3–4 per cent, compared with Trinidad values of 11–27 per cent.

SOIL MOISTURE *v.* WATER-TABLE

From June, 1941 the height of the *water-table* has been measured fortnightly on soils of different type. Sedentary J5/3. Groundwater D2/3. Alluvium A6/2, by means of pipes sunk first to 6′, later (December, 1941) to 10′.

Sedentary

Water has appeared only twice :—at 5′.10″ on 29th May, 1942, gradually falling to below 10′ on 21st August : at 8′.6″ on 2nd November, 1942, falling below 10′ on 23rd November.

Groundwater

Maxima.

18th July, 1942	2′.0″	7th November, 1941	1′.8″
29th May, 1942	3′.11″	30th November, 1942	2′.3″

Minima.

26th September, 1941	5′.1″	24th April, 1942	9′.8″
21st August, 1942	6′.8″.		

Alluvium

Maxima.

18th July, 1941	2′.1″	7th November, 1941	1′.10″
29th May, 1942	1′.9″	2nd November, 1942	0′.4″

Minima.

12th September, 1941	4′.7″	24th April, 1942	8′.0″
5th October, 1942	4′.10″.		

Moisture has been determined in samples taken at 0–6″ : 6–12″ : 12–24″ : 24–36″ from each plot.

Maximum and minimum water-contents of the third foot coincide with maximum and minimum heights of water-table. Maximum and minimum surface moistures are recorded from three to six weeks before the maximum and minimum water-tables.

The only period during which water has been continuously within 2 *feet* of the surface was *Groundwater* 24th October–21st November, 1941.

Periods during which the table has been within 3 *feet* of the surface are *Groundwater* 27th June–22nd August, 1941 : 10th October–5th December, 1941 : 2nd November–16th November, 1942. *Alluvium* 7th June–8th August, 1941 : 31st October–14th November, 1941 : 24th May 12th June, 1942 : 26th October–9th November, 1942.

SOIL MOISTURE AND FOREST SHADE TREES

To find whether forest trees had a beneficial effect by reducing soil moisture during rainy periods and conserving it during the dry seasons, a number of spot samples have been collected and the difference under and outside shade canopies measured relative to the standard error of sampling. No consistently significant results have been obtained.

During the analysis of yields in relation to shade conditions (p. 8), some species of forest trees appeared to be more detrimental to yield than others.

From May, 1941 fortnightly determinations of moisture content were made for one year on composite samples collected from three concentric circles under the following species :—

Erythrina : Tetrapleura (apparently beneficial) : *Triplochiton : Ceiba pentandra : Ficus asperifolia* (apparently detrimental).

The circles were chosen to represent (i) Shade tree only (ii) Shade tree and cocoa (iii) Cocoa only.

The following results were obtained :—

Under *Triplochiton* and *Ficus* moisture is consistently lower than in the unshaded cocoa (iii). There is no significant difference between shade alone (i) and shade + cocoa (ii).

With *Ceiba* and *Erythrina* there is little difference between shaded and unshaded cocoa : moisture under *shade tree only* (i) is *higher* than under cocoa (ii and iii) in *wet periods*.

With *Tetrapleura* moisture under *shade tree only* (i) and *shaded cocoa* (ii) is *lower* than under *unshaded cocoa* (iii) during *dry periods*.

No critical soil-moistures were recorded during the course of the experiment. Measurements will be continued in conjunction with determinations of light intensity.

SOILS

Tafo Station

A preliminary survey of the soils in the northern half of the Station was made in August, 1938.

Thirteen pits, six feet deep, were dug on the various soil types. The profiles have been described and analyses made of samples drawn at 0–6″ : 6–12″ : 1–2′ : 2–3′ : 3–4′ : 4–5′ : 5–6′.

Composite samples (9 points) were taken from 48 $\frac{1}{4}$-acre plots of varying crop yield.

SOIL TYPES

The soils are derived from a biotite granite of the Cape Coast Series. They form a sequence such as has been described for soils of experiment stations of similar derivation (Asuansi : Cadbury Hall, Kumasi).

Red-brown earths, containing varying amounts of concretionary matter, occupy the high ground of the southern boundary and the south west part of the Station : they merge through yellow earths into the grey groundwater soils of the depressions. Alluvial sands of considerable depth are found along the banks of the stream which runs parallel to the northern boundary.

Sedentary (Mature)

The *red earths* are typical of sedentary formation from granite under conditions of free drainage. Four horizons are easily recognized : (*a*) Coarse sand (10–21 inches in depth) ; (*b*) Quartz and ironstone banded in red-brown sandy clay (12–22 inches in depth) ; (*c*) red-brown clay, mottled yellow, changing at about 5–6′ to (*d*) cream friable sandy clay mottled red. This last horizon is of considerable depth, and rock brash is not usually met above 10′.

There is usually a fall in reaction with depth (pH 6·8 to 4·8), a decrease in coarse sand (60 to 15%) and an increase in clay to a maximum of about 40 per cent in the third horizon.

In the *yellow earths*, where drainage is more restricted, the concretionary zone is absent or ill-defined. The surface soils are heavier (clay 20%) and usually more acid (pH 5·8 to 4·5).

Sedentary (Young)

On high ground on the eastern boundary greenish grey rotting rock is met at depths of four to five feet. This is rare in raised granitic soils. It appears to be the result of a high water-table caused by the dip of the parent rock relative to the Voltaian sandstones of the Begoro escarpment ($3\frac{1}{2}$ miles N.E.). Water exudes from the rotting rock.

The surface soil is finer (Fine sand 40–50%) than the average granite soil and is possibly transported. Reaction falls from the surface to the groundwater level, where there is a rapid rise accompanied by an increase in available nutrients.

Groundwater

The upper horizon is colluvial grey sand (0–8″). An iron-stained yellow sand (8–50″) with worn quartz at the base of the horizon passes to greenish grey sandy clay (Clay 27%). There is a marked fall in reaction immediately below the humic zone (6″) from pH 6·0–4·9. Lower horizons have a uniform reaction of about pH 6·0. The groundwater level is clearly defined by iron staining. Below this level there is an increase in soluble nutrients, not high enough to suggest the presence of toxic salts.

Alluvium

A light brown sand of uniform composition (Coarse sand 40. Fine sand 40. Clay 15) and reaction (pH 6·0) throughout its depth.

Termite Mounds

Caps of clay from weathered termite mounds are common on well-drained ground where they persist down to the zone of rotting rock. They are of uniform composition (Clay 40. Fine sand 30%). Reaction increases with depth and free calcium carbonate is present in the lower horizons.

SURFACE SOILS

Good correlation has been obtained in Trinidad between the yield of cocoa and the fertility of the surface six inches of soil. Provisional " Lower Limits of Adequacy " were prescribed for soils of various textures, and an arbitrary system of marking was used to assess their potentiality (4).

During a very thorough examination of 40 six-foot profiles representative of Gold Coast cocoa soils (5), (6), Hardy applied this system to the surface soils and grouped them in classes in good agreement with field performance.

The mean values obtained for the 48 Tafo soils are compared below with Hardy's figures.

	pH	*Carbon*	*C/N*	*Available* P2°5	*Available* K2°	*Rate of Solution*
Adequacy (sand) ...	5·8	1·74	8·5	30	100	—
Gold Coast (Hardy)						
Good (13) ...	6·9	1·97	11·7	41	163	154
Medium (13) ...	6·0	1·22	10·5	20	75	66
Bad (14) ...	5·7	0·81	9·2	18	58	37
Tafo (48) ...	6·6	1·99	11·3	39	124	198

It will be seen that the Tafo soils not only satisfy Trinidad standards, but compare favourably with the best of the Gold Coast cocoa soils.

UNIFORMITY TRIALS

Surface soils have been collected from plots whose yields have been analysed (p. 8) to correlate yield with nutrient status.

Swollen-shoot Disease

The examination of soils from neighbouring patches of good and dying cocoa collected from the "die-back" area of Nankesi in 1934 revealed no significant difference in their general physical and chemical properties (7). Similar negative results were later obtained from the analysis of pairs of soils from healthy and diseased trees in the Swollen-shoot area of Akodum. Trees then described as healthy have since succumbed to the disease.

The suggestion that the disease might arise from a deficiency of minor elements was made by Dade (2) before evidence of its transmissibility was available. Specimens of diseased and healthy tissues, and of soils from affected and unaffected areas were forwarded to England for spectrographic analysis.

The following report was made by Dr. Judd Lewis :—

Soils. No significant difference.

Shoots. Diseased shoots had a lower ash-content, and a relatively higher content of *Silicon*. .

Leaves. Diseased (chlorotic) leaves contained a higher percentage of *manganese* and *silicon*.

It appears likely that the increased percentage of these elements is due to premature senescence ; that they have been immobilized before normal recession from the leaves has occurred.

Deficiency Diseases

iron chlorosis

Typical symptoms of iron chlorosis have appeared—

(i) where plant ash has been incorporated in planting holes ;

(ii) where the lower calcareous horizons of termite mounds have been brought to the surface.

Spraying with 2 per cent ferrous sulphate was found temporarily effective. The tolerance of the light Tafo soils to liming is being investigated in pot experiments.

Sickle Leaf Mosaic

A characteristic leaf distortion and mottling has long been associated with the presence of rotting heaps of cocoa pods. It is also induced by applications of cocoa ash (soluble constituents potassium carbonate and potassium phosphate). Soil analysis of affected and control trees has shown that the condition is associated with high alkalinity and a high content of available phosphate.

Pot experiments and leaf analyses are in progress.

COCOA UTILISATION

To encourage the use of unexportable cocoa a pamphlet *Household Uses for Cocoa* was written. Demonstrations of the preparation of cocoa butter, soap, candles, chocolate and chocolate powder were given throughout the country by Mr. Robert Patterson. A weekly instruction course in their preparation attracted 2,600 students to Tafo during 10 months. A later course given in Kumasi by Mr. Patterson was attended by 2,400 people.

Cocoa butter has not been exportable. The preparation of pure salts of potassium from the ash from burning dumps has been shown to present no difficulty.

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ENTOMOLOGY

(G. S. COTTERELL)

The two chief subjects studied have been the incidence of Capsid pests and the transmission of Swollen-shoot disease.

Minor pests on which observations have been made include the Red-banded Cocoa Thrips (*Selonothrips rubrocinctus*); the moth *Anomis leona*, whose larvae damage flowers and newly-set pods; the leaf-eating Rutelid beetle (*Adoretus hirtellus*) which has caused severe damage to seedling cocoa; *Helopeltis*; Big bug (*Homoeocerus*) and Pod Borer (*Characoma*).

Records have also been obtained of the occurrence of the Braconid parasite of *Sahlbergella*: *Euphorus sahlbergellae*. This parasite, which is hyperparasitised by the ichneumonid, *Mesochorus melanothorax*, parasitises both *Sahlbergella singularis* and the related Capsid, *Bryocoropsis laticollis*. It has not been bred from *S. theobroma*, and attempts to parasitise this species under caged conditions have not been successful.

SAHLBERGELLA AND RELATED CAPSIDS

SPECIES

Sahlbergella spp. *Sahlbergella singularis and S. theobroma.*

An account of the bionomics of these species was published in 1926 (1).

Bryocoropsis laticollis

A Capsid closely related to *Sahlbergella* was found in 1939 to be common on the Station and on the surrounding farms. Its incidence, whilst the tree is carrying pods, was found to be far greater than that of either *S. singularis* or *S. theobroma*: it attacks pods in a much earlier stage of development than those attacked by *Sahlbergella*.

The species was identified as *Bryocoropsis laticollis* Schum.

Its life-history has been worked out from material bred up on caged pods in the field. The following records have been obtained:—

MEAN PERIODS OF DEVELOPMENT OF THE VARIOUS STAGE OF B. LATICOLLIS

Incubation period	1*st* *Instar period*	2*nd* *Instar period*	3*rd* *Instar period*	4*th* *Instar period*	5*th* *Instar period*	*Nymphal life*	*cycle Oviposition to adult*
14·7 days	4 days	3·8 days	3·8 days	3.6 days	4·1 days	19·2 days	33·9 days

The minimum period of development from oviposition to adult was found to be 28 days and the maximum 38 days. The greatest length of life of an individual female was found to be 33

days, the average number of eggs laid by the female being 64, and the largest number of eggs laid at one oviposition being 15. It is probable that under natural conditions the length of adult life and number of eggs laid is considerably higher. When bred on caged chupons and shoots, development from egg to adult is considerably slower.

Eggs are frequently only half-buried in plant tissue and only approximately 50 per cent of eggs hatch. It is therefore concluded that *Bryocoropsis* is not (as yet) a serious pest of cocoa in spite of its numbers, breeding not normally taking place on foliage. Its incidence on cocoa is shown below to be entirely dependent on pod production.

Odoniella apicalis

A Capsid related to *Sahlbergella* was collected by Messrs. Box and Posnette in secondary forest at Asuansi in 1940. It has been identified as *Odoniella apicalis* Reut. & Popp. (sub-family Bryocorinae : family Capsidae).

This is the first record of the species in the Gold Coast. It has been recorded from Spanish Guinea, Togoland and East Africa as breeding on *Piper guineense* and feeding on *Smilax kranssiana*.

Seasonal Distribution :

Periodic collections of Capsid species were made in a heavily infected area of the Station between April, 1939 and May, 1940. The results showed that continuous picking from a small area reduces the insect population and fails to afford an index of normal distribution.

From June, 1940 onwards random collections have been made from 269 quarter-acre plots. One field observer has collected for a fixed period daily. The numbers of each species collected in a month are compared below with the mean evaporation rate (Piche hygrometer) for the month, and with the percentage of the total crop ripening in the month.

Month	*Daily Evaporation mils*	*Total S. singularis*	*Total S. theobroma*	*Total B. laticollis*	*Percentage of total pods ripening*
1940					
June	0·68	53	58	341	2·7
July	0·88	32	107	529	3·4
August	0·79	62	224	968	8·0
September ...	1·01	217	79	2,059	11·6
October	0·98	285	127	3,363	18·6
November ...	0·99	614	59	4,754	31·0
December ...	1·17	522	73	2,291	24·6
1941					
January ...	1·44	1,000	283	137	—
February ...	2·46	633	221	35	—
March	2·79	117	80	3	—
April	1·68	25	77	27	—
May	1·28	1	74	28	—
June	0·98	19	90	35	3·8

Month	Daily Evaporation mils.	Total S. singularis	Total S. theobroma	Total B. laticollis	Percentage of total pods ripening
1941—*contd.*					
July	0·79	17	107	133	2·0
August	0·85	36	94	201	5·5
September ...	1·00	51	33	426	33·8
October	0·90	166	72	584	33·2
November ...	1·32	243	45	487	14·5
December ...	1·05	238	99	200	7·2
1942					
January ...	1·49	274	105	26	—
February ...	1·89	171	106	1	—
March	1·63	70	79	5	—
April	1·38	Method of collection changed.			
May	0·78	,, ,, ,, ,,			

Bryocoropsis laticollis

The population appears to be closely dependent on the number of ripe pods available. Peak population was reached earlier in 1941 than in 1940 when the harvest was later.

Sahlbergella singularis

Numbers increase from August, as favourable breeding material in the shape of ripe pods becomes available, and reach a peak in January when, after all pods have been harvested, breeding is transferred to the new flush which follows harvesting. There is then a fall in numbers, which is particularly rapid when the dry season is severe (1941).

Sahlbergella theobroma

Distribution is irregular, with apparent peaks in July–August and January–February.

CRITICAL HUMIDITY AND TEMPERATURE

The reduction in numbers of *Sahlbergella* spp., which follows the dry season suggested that low humidity or high temperature might be a limiting factor.

Without a drying chamber sufficiently large to accommodate entire plants it has been difficult to assess the effect of relative humidity : using detached shoots it is uncertain whether the food supply is attractive. Results so far obtained indicate that a relative humidity of about 60 per cent is critical. Whether this is a direct effect or due to starvation resulting from the increased sap pressure is not known.

Adults and nymphs of both *S. singularis* and *S. theobroma* were found able to withstand a temperature of 90°F. for 48 hours. The upper lethal temperature is therefore not likely to be reached in the cocoa belt.

DAMAGE TO FOLIAGE

Since October, 1940, a bi-monthly survey of damage caused to foliage by Capsids has been carried out on 269 plots. The numbers of plots showing varying degrees of damage are recorded below.

	1940			1941			1942		
	Very bad	Bad	Slight	Very bad	Bad	Slight	Very bad	Bad	Slight
January ...	11	71	99	5	19	91	2	25	59
March ...	32	64	105	7	26	74	3	27	58
May	25	84	103	0	4	60	4	22	50
July	6	57	133	0	3	27	2	25	62
September ...	3	24	90	0	4	27		No record	
November ...	4	18	79	1	10	44	5	23	42

Damage was most severe in May, 1940, and lowest in July-September, 1941. Damage during 1942, has been remarkably uniform in amount and degree. The survey has shown that certain plots have consistently remained free from damage, whilst others have been repeatedly attacked.

DAMAGE TO PODS

In 1938–39 records were kept of damage to harvested pods caused by *Sahlbergella* spp., *Helopeltis*, Thrips (*Heliothrips*), Big Bug (*Homoeocerus*) and Pod Borer (*Characoma*) on all Station plots. The results have not yet been analysed. Since 1939, records of pod damage have been kept only on a selected number of plots.

Control

BY PREDATORS

Red Tree Ant

Experiments made at Asamankesi in 1926 had indicated that the *Sahlbergella* population is reduced by the presence of the Red Tree Ant (*Oecophylla longinoda*).

A survey of the Station plots made in 1940, showed that the percentage (number) of trees infected by the ant ranged from 0 to 50 per plot : the average percentage was 10 : no correlation could be obtained between the ant population and the degree of Sahlbergella damage. Attack was frequent on plots in which 50 per cent of the trees were infected with *Oecophylla*.

Transference of nests of the ant, together with the scale in mobile form, to trees heavily infested with *Sahlbergella*, caused no notable reduction in infestation. *Sahlbergella* nymphs were observed feeding on a branch on which the ants had established not only scale but their nest. An essential condition for the establishment of the ant is that the tree shall be carrying a recent flush on which young scales (*Stictococcus spp.*) can be established in the mobile form. Should there be sufficient favourable wood for both *Sahlbergella* and scale to survive during their immature stage it appears that the ant will not attack *Sahlbergella*.

Rhinocoris loratus

A Reduviid predator which is an important check to both *Sahlbergella* and *Bryocoropsis* has been identified as *Rhinocoris loratus* (Harpactor loratus.)

BY PARASITES

Euphorus sahlbergellae

An estimate of the seasonal variation in parasitism of *B. laticollis* and *S. singularis* by *Euphorus sahlbergellae* was made between April, 1940 and March, 1941. Nymphs of both species were caged with detached shoots and pods ; the number of *Euphorus* cocoons formed was counted.

Month	No. of Nymphs		No. of parasite cocoons obtained		Percentage parasitism	
	S. singularis	*B. laticollis*	*S. singularis*	*B. laticollis*	*S. singularis*	*B. laticollis*
April 1940 ...	178	—	17	—	9·5	—
May	66	137	3	11	4·5	8·0
June	29	295	0	7	0·0	2·3
July	49	405	0	3	0·0	0·7
August	32	714	0	1	0·0	0·1
September ...	89	680	2	2	2·2	0·3
October ...	221	741	0	15	0·0	2·0
November ...	304	1314	5	41	1·6	3·1
December ...	412	1379	5	27	1·2	1·9
January 1941 ...	852	129	40	10	4·7	7·7
February ...	514	12	34	0	6·6	(0·0)
March	85	0	16	0	11·7	(0·0)

It is probable that these figures are considerably lower than those occurring in the field on account of the high mortality rate of the host when reared on pods and shoots detached from the plant.

Parasitised nymphs can be recognized when the parasite is sufficiently developed. By picking obviously parasitised specimens from samples of nymphs of *B. laticollis* in November, 1940, a percentage parasitism of 8·2 per cent was obtained, compared with 3·1 per cent determined in the cage experiment.

BY SPRAYING

The irregular distribution of Capsid damage seemed likely to upset the results of a number of the Station experiments. Periodic sprayings have been necessary.

Field trials were made with the following insecticides :—

(*a*) *Nicotine sulphate* (40%)

1 : 1000 Mortality 100%
1 : 1500 Mortality 100%
1 : 2000 Mortality 90%

(*b*) *Lime-sulphur*

1 : 50 Mortality 50–75%, with considerable leaf scorch
1 : 100 Mortality under 10%.

(*c*) *Tropical Mortegg* (Tar and petroleum oil distillates. Proprietary).

1 : 50 Mortality under 75% Severe leaf scorch.
1 : 100 Mortality under 50% Severe leaf scorch.

Pyrethrum and Derrimac (derris and nicotine) dusts were successful in laboratory trials. Field trials have not been made. Used with an efficient duster it is probable that Derrimac would be cheaper than nicotine sulphate.

APPLICATION

Good contact is necessary. In treating trees with full-grown canopy a power sprayer working at high pressure is needed to cover new flush completely.

A Craven " Hydraulus " power unit working at 200–350 lb. per square inch has been used with two spray guns of variable jet size. The machine weighs 240 lb. and can be head-loaded along narrow bush paths. With this machine three to four acres of full-grown cocoa can be sprayed in a day.

Using 114 gallons of spray (Nicotine sulphate (40 per cent) 1 : 1,000) per acre the cost of spraying was 9s. 3d. per acre, (Nicotine 4s. 3d. : Labour 2s. 11d. : Soap 1s. and 5d. : Petrol 6d. : Oil 2d.).

SWOLLEN-SHOOT VIRUS

INSECT TRANSMISSION

Preliminary *field trials* with 10 species of Hemiptera were started in May, 1940. Suspected vectors were collected from infected trees and caged with muslin on three year old seedlings removed from infected areas : no outbreak of Swollen-shoot occurred on control seedlings in the area. Transmission was obtained in one out of eleven cages infected with the Cocoa Psyllid (*Mesohomotoma tessmanni*, Aulm.), swellings developing 20 weeks after infestation. No other case of transmission was observed during 12 months.

Further trials were made early in 1941 after the insectary had been built.

TECHNIQUE

Healthy one-year seedlings from a disease-free area were planted at 2 feet intervals in concrete troughs in the insectary. Experimental plants were screened with muslin covered wooden cages 2′ x 2′ 6″ x 5′ high, controls being left uncaged. Each plant was grease-banded 6 inches above soil level and cut back periodically to induce new flush. The plants grew well and produced new flushes at approximately monthly intervals.

Plants were infested with the species of insect under trial as frequently as possible. With those insects dependent on tender foliage for their development infestations were made only during periods of new flush.

The above technique made it difficult to prevent accidental infestation by Mealy Bug and Cocoa Aphis. Each species needs

to be segregated in a different part of the insectary. In later trials potted plants are being used which can be moved to different parts of the insectary and protected from infestation by other insects via the soil.

Buds from all plants showing symptoms of infection are grafted on to healthy plants to confirm the presence of the disease.

POSITIVE RESULTS

1. *Cocoa Psyllid* (*Mesohomotoma tessmanni*), *nymphs.*

Plants infested six. Transmissions six. A total of 91 insect (nymph) transferences was made.

First symptoms were typical mosaic on new flush, the shortest period between infestation and the development of mosaic being 38 days. There was one case of non-virulent infection in which shoots grew through a large nodal swelling and mosaic gradually became less pronounced on succeeding flushes. Usually the plants have died back rapidly. Swellings have occurred from 17 to 39 days after chlorosis had been observed.

There have been accidental infestations by Mealy Bug and Aphis in some of the cages but it can be taken as conclusive that transmission has been caused by the immature Psyllid.

2. *Mealy Bug* (*Pseudococcus* sp. No. 1453).

Plants infested three. Transmissions three. A total of 18 insect transferences was made.

There was no accidental infection. First symptoms were chlorosis, leaves falling off before hardening. First infection was apparent 187 days after infestation, swellings appearing 57 days later.

3. *Mealy Bug* (*Ferrisiana* (*Pseudococcus*) *virgata*).

Plants infested five. Transmissions two. A total of 46 insect transferences was made.

No accidental infection. Mosaic and leaf fall 187 and 228 days after infestation.

4. *Cocoa Aphis.* (*Toxoptera aurantis*)

Plants infested six. Transmissions two. A total of 56 insect transferences was made.

No record of accidental infection. In the first transmission Mosaic appeared 139 days after infestation. Large terminal swellings, through which shoots subsequently grew, appeared nine days later. Apparently non-virulent type.

DOUBTFUL RESULT

Cocoa Psyllid (*Adult*)

Plants infested six. Transmission one (?). A total of 59 insect transferences was made.

Mosaic with subsequent swellings appeared 509 days after infestation. During this period there had been numerous infestations by Mealy Bug and one by Aphis.

NEGATIVE RESULTS.

The following insects, tried either in the field experiment (F) or in the insectary experiments (I) have so far given no indication of transmission. It cannot yet be accepted that they are not vectors.

Thrips.—*Selanothrips rubrocinctus*, Giard. FI
Capsid—*Bryocoropsis laticollis*, Schum. F
Fulgorid—No. 1345 ... ... F
Dictyophorid—*Criphyle sp.* ... ... F
Ricaniid—*Ricania mediana, Mel.* ... I
Ricanopsis semihyalina, Mel. I
Ricanopsis nebulosa, Mel. ... I
Epitemna carbonaria, Walk. ... I
Pochazia fasciata. F. ... ... F
Membracid—*Gargara* sp. ... ... F
Cercopid—*Unnamed* ... ... F
Coccid—*Strictococcus sjostedtl*, Ckll. ... I
No. 1390 I
Coreid—*Cletomorpha lancigera*, F. ... F

OTHER TRIALS.

Experiments are in progress with Psyllid nymphs to determine :—

(i) the minimum feeding time on infected and healthy plant needed for transmission.
(ii) whether they can transmit the disease to and from *Cola acuminata*.
(iii) whether they can transmit " Mottle-leaf " (Kpeve) virus.

Further experiments are necessary to find :—

(i) the distance which the Cocoa Psyllid can be carried by wind ;
(ii) whether infected vectors can transmit the disease to their progeny ;
(iii) whether Mealy Bug and Aphis are capable of transmission ;
(iv) whether different strains of the disease are carried by specific vectors.

Bionomics of Proved or Suspect Vectors

Cocoa Psyllid

An account of the bionomics of this insect was published in 1927 (2). Life-history stages have been redetermined as :—Egg period 4–8 days : Nymphal period 7–11 days : Adult life 1–19 days.

Adult life under field conditions is probably much longer.

Incidence is normally correlated with the degree of flush. It is greatly reduced by heavy rainfall. Immature stages are gregarious, and transference over any considerable distance would be dependent on wind carriage. Adults move from tree to tree by a hop and glide motion.

Two internal parasites of the immature stage have been bred out. Neither appears to be common.

Known alternative host plants include *Cola spp., Sterculia tragacantha, Glossolepis pilgeriana.*

Mealy Bug

Egg stage one day. Two to three days after hatching nymphs scatter over the ground. *Nymphal stage.* Variable for both species, dependent on food supply. (*Ferrisiana* 30–90 days). Maturing females migrate from tree to tree via the ground.

A wide range of host-plants has been recorded for *Ferrisiana.* This species is not cultivated by ants as is the other suspect *Pseudococcus.*

Cocoa Aphis

Colonies are confined to new flush and congregate on the under surface of leaves. Migration from plant to plant is made by winged females.

CONTROL

After transmission by the Cocoa Psyllid had been obtained in the Field Trials spraying to prevent the spread of possibly infected insects was incorporated in routine treatment. The whole of the infected area and a peripheral ring 50 yards deep were sprayed prior to cutting out infected trees and a ring of healthy contacts. A second spraying was given a fortnight later.

Observations on the effect of various insecticides were made in conjunction with the trials with *Sahlbergella* (p. 50) Nicotine sulphate (40%) was effective at a strength of 1 : 1,500 provided sufficient pressure were applied to penetrate thick canopy. The wax covering of nymphs renders dusts inoperative.

Two " Hydraulus " power units, each working two spray guns, have been in regular use.

Using Nicotine sulphate (40%) 1 : 1,500 at the rate of 150 gallons per acre the double treatment of diseased and contact areas at Kwabeng was estimated to cost £1 18s. per acre. This included the felling of trees in the diseased area, which was about one-sixth of the total area sprayed.

From the beginning of 1941 spraying has been carried out in the treatment of 35 outbreaks. (Nkawkaw district 13 : Pamang 10 : Boma 6 : Bunsu 3 : Kwabeng 2 : Banso 1).

Spraying was discontinued in September, 1942, after evidence of transmission by insects other than Psyllid had been obtained.

STORED COCOA

The inert dust Neosyl was applied to dry cocoa at rates of 0·1% and 0·2%. Counts of *Araecerus, Ephestia, Lasioderma* and total insects made after nine months' storage showed the dust to have been ineffective against any of the insects attacking prepared cocoa. (Percentage purity Treated 65%. Untreated 73%).

Failure is probably due to the size of the interstices between seeds.

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PATHOLOGY

(A. F. Posnette)

Research on diseases of cocoa has been confined almost entirely to the problem of Swollen-shoot virus disease. Observations have been made on root diseases and canker, and an investigation has been made of the cause of an obscure pod disease termed Warty Pod, but this report will deal only with the results of Swollen-shoot investigations.

SWOLLEN-SHOOT VIRUS DISEASE

An account of the work carried out prior to 1941 by Wright, Steven, Dade, Deighton, Shepherd and Posnette has been published(1). Reference to this paper is recommended.

HISTORY

The disease was discovered at Effiduase in 1936, and first described by Steven(2) in November, 1936. There is, however, little doubt that it had been present at Nankese before 1930 and had been responsible for the extensive " dieback " reported in that year. When it is considered how seldom swellings are produced, and how inconspicuous they are, in the virulent form of the disease, it is not surprising that before 1936 it had been confused with other forms of dieback.

Although unable to isolate a pathogen likely to be a primary parasite, Steven recognised the infectious nature of the disease, and on his recommendation 81,000 trees were cut down in 300 farms. It soon became apparent that the disease was more widespread than had been anticipated. Diagnosis was based on the presence of swellings, and failure to recognise earlier symptoms led to the re-appearance of the disease in farms treated only a few months previously.

Cutting-out was discontinued in 1937 after Dade(3) had concluded that the " evidence points to a physiological and not to a parasitic diagnosis." It was followed by a tree-planting campaign designed to improve environmental conditions and to eliminate drought dieback, of which Dade thought the disease to be a symptom.

Evidence that the disease was graft-transmissible had been obtained at Tafo in 1939. Subsequent work has established it as a virus with characteristics similar to those recorded for virus diseases of other fruit trees.

Symptoms

A description of the symptoms characteristic of the various strains of the disease has been prepared for the use of field observers(4).

Before 1940 diagnosis rested on the discovery of swellings, for which careful search had to be made in areas showing the accompanying symptoms of defoliation, dieback and excessive bud stimulation. As swellings are difficult to distinguish, and develop at varying periods after infection, many infected trees were left standing during the early cutting-out campaign.

More accurate and timely diagnosis was made possible after budding experiments, carried out by the Botanist, had shown that a mosaic form of chlorosis is a much earlier symptom of infection by most strains, and that trees are infective before any symptoms at all have developed. These discoveries led first to the cutting out of trees showing mosaic and later to the cutting-out both of trees showing mosaic and of trees adjacent to them. This practice has greatly increased the efficiency of field control.

During 1942 a series of experiments was started to investigate the behaviour of the virus in the plant. Details of these experiments will be published elsewhere but the following conclusions are of interest :—

The virus passes from scion to stock within ten days of grafting.

The first symptom to appear is always vein-clearing in young leaves. It usually develops from 10 to 20 weeks after infection (five weeks minimum recorded), depending on the incidence of flushing.

Neither the number of infecting buds, nor their position on the stock, has any apparent influence on the time at which symptoms first appear, or on their severity.

Ring barking at least delays the passage of the virus along the branch of the tree.

The heat inactivation point of the virus in budwood is higher than 45°C. for 30 minutes and 50°C. for 12 minutes, the lethal points of the budwood itself.

Strains

Transmission by grafting under similar environmental conditions has established that there are several strains of the wollen-shoot virus, and probably more than one virus, infecting cocoa. The range of symptoms follows a close parallel with the Peach virus complex in the U.S.A. of which the writer obtained first-hand information in 1941.

The relationship between the cocoa viruses has been studied by double inoculations, which have indicated that the " Bisa " type is a mild strain of the Swollen-shoot virus, and capable of conferring some degree of immunity against the prevalent virulent (New Juaben) strain.

The Kpeve type, on the contrary, does not confer immunity and is probably a distinct virus, to be known as " Mottle Leaf ". Other strains are under investigation.

TRANSMISSION

By Inoculation.—The following inoculation experiments had been made by Shepherd prior to 1940 :—

(*a*) *Injection*

Sap obtained from affected stem-tissue was injected into (i) the young branches (ii) the petioles (iii) the leaf midribs of cocoa seedlings. Control seedlings were injected with distilled water. A number of replicates was used.

No transmission occurred.

From cultures of sap from healthy and diseased tissue only one dominant organism was obtained ; a bacterium common to extracts from both diseased and healthy shoots.

(*b*) *Contact*

No transmission was obtained by the passage of a needle or a scalpel through joined surfaces of infected and healthy tissue or by the contact of surfaces abraded by carborundum powder or the rough leaves of *Ficus asperifolia*.

It was concluded that transmission can be effected only by the contact of living cells or by the agency of specific vectors.

By Grafting.—Transmission by grafting was first obtained at Tafo in 1938 ([5]) and later confirmed in a large-scale experiment conducted at Aburi in 1939. In this experiment a careful study of the root systems of affected trees was made. No signs of root disease were apparent.

As Aburi was situated in an area free from infection it was necessary to destroy the budlings soon after definite symptoms had appeared. This has been the fate of most plants experimentally infected at Tafo before 1942, the only exceptions being four caged plants which were infected by budding for the study of progress of the disease.

The shade, higher humidity inside the cage, and the protection from insect attack, should have helped the plants to resist the effects of the virus. All have died ; a seedling budded in July, 1939 died in December, 1940 ; a nine-year-old tree budded in January, 1940 died in March, 1941, in spite of watering during the dry season. On the other hand, a second tree of the same age also budded in January, 1940, survived until April, 1942, and a seedling budded in November, 1938, did not die until June, 1942. In each of these examples, the control plants are growing vigorously under identical conditions.

Including tests made on " resistant " selections (*see* pp. 24 and 25) transmissions by grafting now number several hundred. Except in the case of a few tolerant clones the stock has habitually shown symptoms within six months of budding with infected budwood. Budding is at present used for testing doubtful cases of infection discovered on native farms.

By Seed.—Experiments with seed transmission have given conflicting results. Stunting and swellings, but not typical mosaic,

are evident among seedlings from dwarfed pods taken from trees infected with the virulent strain of Swellen-shoot. Many such dwarfed pods have yielded only healthy seedlings, however, and it appears that seed transmission may occur, but rarely.

By Pollen.—Experiment to test transmission through pollen, gave negative results. Neither mother trees, nor resulting seedlings developed symptoms after cross-pollination with infected trees.

Rate of Spread

Tafo

There are two types of spread—the gradual progression of the virus by the infection of neighbouring trees, and the random appearance of new scattered outbreaks some distance from the first. The increase in the number of outbreaks on the Station from one in February, 1939 to 81 in December, 1942 indicates the rate of formation of new outbreaks. The rate of progressive spread has been observed on marked plots in native farms near Tafo, Apedwa, Suhum, Huhunya and Bisa.

In July, 1940 two areas near Tafo were inspected, individual trees labelled and their health described, and a monthly diary started for each tree. The observations are summarised below :—

Rate of Progressive Spread at Tafo
No. of infected trees by March

	1940	1941	1942	1943
1st outbreak ...	37	86	123	Cut
2nd outbreak ...	31	62	73	92
3rd outbreak ...	—	—	8	30
4th outbreak ...	—	—	6	8

It should be remembered that these figures do not take into account new diseased areas developing within a few yards of the original infected patch which was spot-planned. This sporadic dispersal of the disease is the chief cause of the rapid devastation of farms.

Apedwa

No opportunity was found to label trees in the more distant areas in which infected trees had been marked with paint. At Apedwa, the rate of spread during the year can be assessed only roughly in terms of distance. The area infected has increased 20 times in five years.

Rate of Spread of Apedwa Outbreak in feet

	North	*N. East*	*East*	*S. West*	*West*	*N. West*
October, 1937 to April, 1940 ...	10	30	13	60	—	—
October, 1937 to January, 1941 ...	132	84	48	66	36	45
October, 1937 to April, 1942 ...	159	128	123	166	51	72
October, 1937 to January, 1943 ...	264	230	258	234	156	141

Alternative Host Plants

The discontinuous distribution of outbreaks over a large proportion of the forest belt of the Gold Coast, and the frequent recurrence of fresh outbreaks near Tafo, can be explained satisfactorily only on the assumption that the virus is harboured by alternative host plants. That these are indigenous is suggested by the frequent occurrance of outbreaks near Forest Reserves and by the absence of the disease from other cocoa-growing countries. Additional evidence is afforded by the number of cases in which native farmers have connected the first appearance of the disease with the felling of forest trees. On the Station itself two outbreaks appeared after trees had been damaged by the falling of a *Triplochiton scleroxylon* (Sterculiaceae) in one instance and a *Ceiba pentandra* (Bombacaceae) in the other.

Surveys of infected areas failed to suggest any particular species as likely sources of infection. The problem has therefore been approached in two ways.

It is most likely that the virus originated in plants nearly related to cocoa. Attempts were therefore made to transmit the virus from cocoa to indigenous species in the *Sterculiaceae*, *Tiliaceae* and *Bombacaceae* by approach-grafting.

This method was first tried with the only other species of *Theobroma* available, *T. bicolor*, seedlings of which developed mosaic and leaf crinkel after approach-grafting to infected cocoa seedlings. These symptoms were proved to be due to the Swollen-shoot virus by their transmission through grafts to healthy cocoa seedlings.

With indigenous plants the experiments have not yet reached the back-grafting stage, but possible virus symptoms have been induced in *Bombax buonpozense*, *Cola acuminata* and *Sterculia tragacantha*.

The second approach to the problem was by the collection of all mosaic diseases of woody plants, and the investigation of their virus nature by grafting.

Mosaics resembling virus symptoms have been found on the following trees :—

Combretaceae	:	*Terminalia superba*
Bombacaceae	:	*Ceiba pentandra*
Sterculiaceae	:	*Sterculia tragacantha*
		Erythropsis barteri
Euphorbiaceae	:	*Ricinodendron africanum*
Leguminosae	:	*Albizzia zygia*
		Dalbergia sp.
		Milletia sp.
		Lonchocarpus sp.
		Erythrina altissima
Moraceae	:	*Ficus asperifolia*
		Myrianthus arborens
Meliaceae	:	*Trichelia sp.*
Compositae	:	*Vernonia amygdelina.*

Control

By Cutting-out.—A paper describing the treatment of infected areas on Tafo Station has been prepared (6) for publication. It is necessary only to say that small outbreaks have been cleared up successfully by the removal of infected and suspected trees, without spraying.

So far the disease has never been eliminated by this means from large infected areas at the first operation. Even with the additional precaution of removing contiguous healthy trees and spraying, the spread of the disease has not been stopped entirely. It should be stressed, however, that many, perhaps most, of the fresh infections found after the treatment of an area, are trees that had been infected before treatment, but had not yet developed symptoms; this is indicated by the period between treatment and the appearance of fresh infection being shorter than that between infection and symptoms in transmission experiments. It is therefore reasonable to hope that repeated drastic action, not only on the Station but in neighbouring farms, will keep the disease under control.

Unless this can be done there are poor prospects of obtaining valid results from any manurial, cultivation or progeny trials laid down at Tafo. Much depends, however, on the discovery of the alternative hosts of the virus, and on the success of Capsid control, without which replanting is unlikely to be successful.

The Station cocoa and farms within 280 yards of its eastern boundary have been searched systematically for outbreaks each month. The advantages of this continuous survey are reflected by the early stage at which outbreaks are dicovered. The average number of infected trees per outbreak discovered on the Station in 1942 was two, it had been three in 1941 and eight in 1940. Early removal of infected trees and apparently healthy contacts has stopped the spread in all but four of the 73 outbreaks treated more than six months ago. The number of new outbreaks found each month has not diminished, however; 40 new outbreaks were found in 1942, as compared with 14 in 1941, and 17 in 1940. By December, 1942, 81 outbreaks had been treated on the Station, and 87 outbreaks on neighbouring farms.

An experiment started in November, 1941 to find out whether the disease could be eliminated from large outbreaks by the removal of up to two complete rings of healthy trees round those infected, together with spraying or burning to destroy vectors, has produced disappointing results.

Although outbreaks of up to ten trees can be controlled with one treatment, repeated operations are usually necessary for clearing up larger areas.

An interesting outcome of the treatment given to outbreaks on Tafo station is the absence of subsequent "exposure", or physiological, lieback. The gaps have been filled with Plantains and quick-growing trees, but there is, necessarily, a considerable period when remaining trees are exposed. With the exception of

trees which are found later to be infected, the surrounding trees have shown no ill-effects ; in fact their vigour has often increased even when the cutting out was done in the dry season. It is realised, of course, that the result would have been very different had Capsid attack been as severe as in previous years, but this further supports the view that most of the supposed " exposure dieback " in the wetter areas is really due either to insect attack or to virus infection.

By Immunisation.—The discovery of the mild " Bisa " strain, which is the only form of the disease not characterised by obvious leaf symptoms, suggested the possibility of immunising plants against more virulent strains. In March, 1941 four young cocoa trees, which had fully developed symptoms of the mild strain after grafting a year previously, were infected with the virulent strain. Five months later the new flush on these trees was chlorotic, and it was decided to destroy three of them to avoid disseminating the virulent strain. The fourth was caged : subsequent flushes on this tree have been healthy.

Early in 1942 the experiment was repeated using both the Bisa and the Kpeve strains. These experiments, while apparently confirming the immunisation by the Bisa strain, have shown that the Kpeve strain confers no immunity and is probably a distinct virus.

A 10-acre field trial has been laid down on the Department's observation plot at Mangoase, where there are several outbreaks of the virulent strain. This experiment is designed to give information on the possibility of using immunisation by bark grafts to preserve farms remaining healthy in heavily infected districts. Very little is yet known about the effect of the Bisa strain on yield and vigour.

By Selection of Resistant Strains.—See Botany p. 24 and 25.

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(5) Posnette, A. F. (1940). *Trop. Agr.* XVII 5. p. 98.

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(Submitted to *Tropical Agriculture* April, 1943).

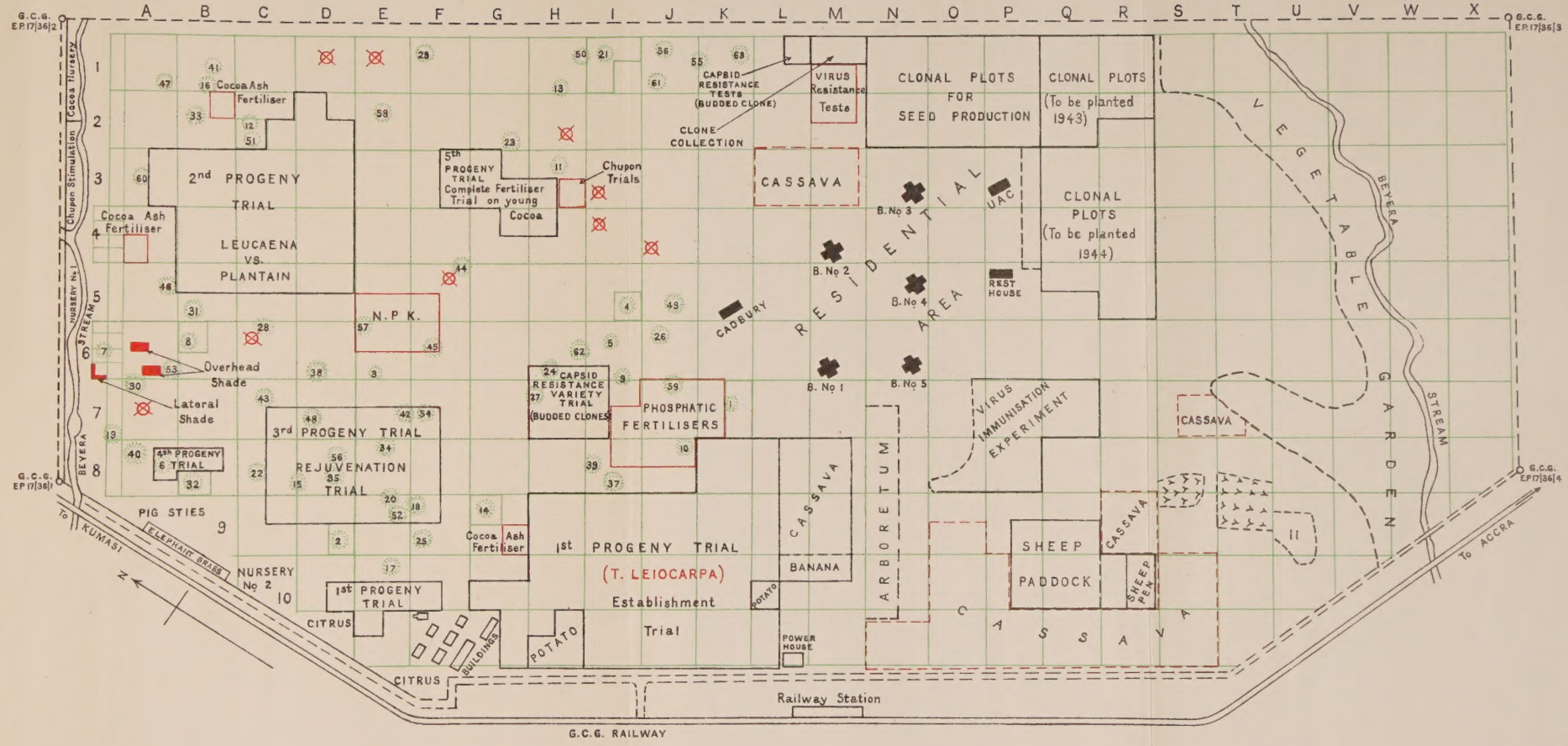
METEOROLOGY

		Av. shade max.	*Av. shade min.*	*Relative humidity 3.0 p.m.*	*Rainfall inches*	*No. of wet days*	*Total hours Sunshine*
January ...	1938	87	69	—	1·35	2	—
	1939	89	66	56	2·17	6	227·9
	1940	86	71	59	1·11	5	201·0
	1941	86	69	60	0·92	8	213·5
	1942	87	68	56	1·93	4	227·6
February ...	1938	91	69	—	2·82	7	—
	1939	90	67	59	3·82	7	191·6
	1940	88	72	59	5·54	5	206·4
	1941	90	71	52	2·81	5	204·7
	1942	89	73	56	5·59	8	204·6
March ...	1938	90	70	—	3·71	10	—
	1939	91	70	60	6·54	14	193·9
	1940	89	71	59	2·48	8	194·8
	1941	90	73	67	5·65	13	188·6
	1942	90	72	57	4·42	10	221·9
April ...	1938	90	70	66	7·01	12	176·9
	1939	91	70	62	7·64	6	222·0
	1940	89	71	64	6·54	13	206·4
	1941	88	73	60	4·50	9	182·1
	1942	89	71	67	4·80	11	207·4
May	1938	89	70	70	5·87	15	190·3
	1939	90	71	66	7·40	12	184·4
	1940	87	72	69	4·25	13	182·7
	1941	86	72	66	7·30	16	149·5
	1942	86	71	73	15·80	21	144·0
June ...	1938	86	71	74	6·21	18	130·7
	1939	87	69	73	8·75	21	152·7
	1940	83	71	74	9·11	21	117·2
	1941	86	73	73	7·78	19	140·9
	1942	83	72	72	6·56	16	113·6
July	1938	85	69	70	3·60	11	127·8
	1939	84	70	74	13·94	18	126·3
	1940	79	70	72	2·81	11	75·1
	1941	82	72	74	5·20	10	105·2
	1942	79	70	71	2·48	8	83·2
August ...	1938	82	68	68	2·76	10	109·1
	1939	83	70	76	4·06	16	91·3
	1940	81	70	70	4·98	17	81·7
	1941	81	72	71	1·68	8	88·9
	1942	80	69	67	0·26	5	65·5
September ...	1938	85	70	73	4·63	19	110·4
	1939	82	70	65	5·45	17	91·4
	1940	83	72	67	6·27	13	96·8
	1941	84	72	69	7·04	17	119·4
	1942	84	71	69	4·69	13	102·8
October ...	1938	89	70	66	6·04	22	157·8
	1939	84	70	66	9·57	14	142·1
	1940	86	72	70	10·36	17	159·7
	1941	86	72	70	7·23	12	169·3
	1942	85	71	71	7·80	19	162·6
November ...	1938	90	69	65	7·00	15	212·7
	1939	86	70	67	11·23	15	177·7
	1940	87	70	69	3·20	13	197·5
	1941	87	72	61	3·85	7	206·4
	1942	87	71	66	3·71	8	217·8
December ...	1938	89	70	65	4·33	10	206·4
	1939	86	71	65	4.40	10	220·4
	1940	88	72	57	0.27	2	227·4
	1941	87	71	61	2·63	8	223·5
	1942	86	67	66	1·41	7	234·4

G.P.D. /W. 2823 /300 /8 /43

TAFO

CENTRAL COCOA RESEARCH STATION



LEGEND

⊠ = Individually recorded plots. 47 = Swollen shoot patch. ▭ = Swollen shoot centre squared off. ▨ = Cocoyam root rot trials.

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